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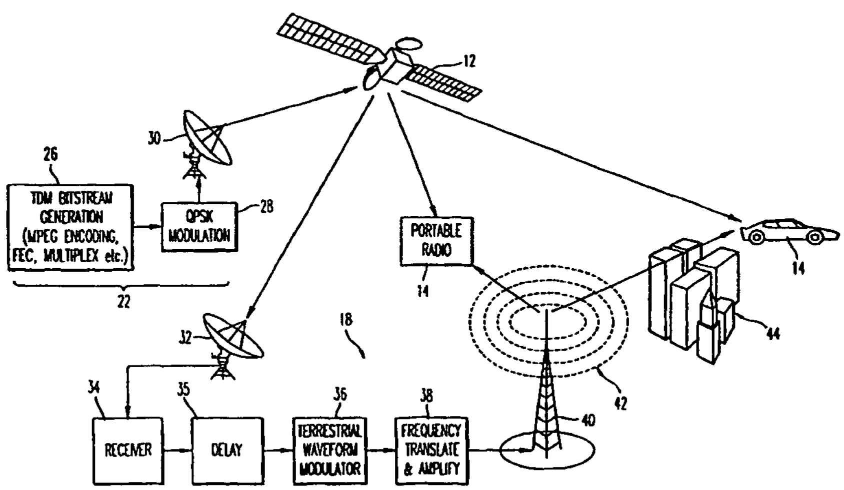

(57) Abstract

A digital broadcast system is provided which uses a satellite direct radio broadcast system having different downlink modulation options in combination with a terrestrial repeater network employing different re–broadcasting modulation options to achieve high availability reception by mobile radios (14), static radios and portable radios (14) in urban areas, suburban metropolitan areas, and rural areas, including geographically open areas and geographic areas characterized by high terrain elevations. Two–arm and three–arm receivers are provided which each comprise a combined architecture for receiving both satellite and terrestrial signals, and for maximum likelihood combining of received signals for diversity purposes. A terrestrial repeater is provided for reformatting a TDM satellite signal as a multicarrier modulated terrestrial signal. Configurations for indoor and outdoor terrestrial repeaters are also provided.

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DIGITAL BROADCAST SYSTEM USING SATELLITE DIRECT BROADCAST AND TERRESTRIAL REPEATER

Field of Invention

A digital broadcast system is provided which uses a satellite direct radio broadcast system having different downlink options in combination with a terrestrial repeater network employing different re-broadcasting options to achieve high availability reception by mobile radios, static radios and portable radios in urban areas, suburban metropolitan areas, rural areas, including geographically open areas and geographic areas characterized by terrain having high elevations.

Background of the Invention

Receivers in existing systems which provide digital audio radio service (DARS) have been radically affected by multipath effects which create severe degradations in signal quality, such as signal fading and inter-symbol interference (ISI). Fading effects on broadcast channels to receivers can be sensitive to frequency, particularly in an urban environment or geographic areas with high elevations where blockage of line of sight (LOS) signals from satellites is most prevalent. Locations directly beneath a satellite (hereinafter referred to as the sub-satellite point) inherently have the highest elevation angles, while locations that depart from the sub-satellite point inherently have decreasing elevation angles and, accordingly, an increase of the earth center angle subtended between the sub-satellite point and the reception location. Locations that are near the sub-satellite point typically enjoy virtually unblocked LOS reception. Thus, the need for terrestrial reinforcement of potentially blocked LOS signals is minimal. When the LOS elevation angle to the satellite becomes less than about 85 degrees, however, blockage by tall buildings or geological elevations (i.e., on the order of 30 meters) becomes significant. Terrestrial re-radiation for gap filling is needed to achieve satisfactory coverage for mobile radios, static radios, as well as portable radios. In areas where the heights of buildings or geological sites are relatively low (i.e., on the order of less than 10 meters), the blockage is not significant until the LOS elevation angle is lower than 75 degrees. Thus, at the mid-latitude and high latitude locations within the coverages of one or more broadcast satellites, terrestrial re-radiation is needed to achieve suitable radio reception. A need exists for fully satisfactory radio reception that combines satellite LOS transmission and terrestrial re-radiation of a satellite downlink signal waveform.

Summary of the Invention

In accordance with one aspect of the present invention, a digital broadcast system (DBS) is provided which overcomes a number of disadvantages associated with existing broadcast systems and realizes a number of advantages. The DBS of the present invention comprises a TDM carrier satellite delivery system for digital audio broadcasts (DAB) and other digital information which is combined with a network of terrestrial

repeaters for the re-radiation of satellite downlink signals toward radio receivers. The terrestrial repeaters are configured to employ multipath-tolerant modulation techniques.

In accordance with another aspect of the present invention, a satellite delivery system and a terrestrial repeater operate using different carrier frequencies. The terrestrial repeater employs multipath-tolerant modulation techniques.

In accordance with yet another aspect of the present invention, a satellite delivery system and a terrestrial repeater both employ multipath-tolerant modulation techniques and can be configured to use the same or different carrier frequencies, depending on the type of waveform used. The satellite delivery system preferably employs a TDM or code division multiple access (CDMA)-type waveform. The terrestrial repeater preferably employs a multipath-tolerant waveform such as CDMA, Adaptive Equalized TDM (AETDM), Coherent Frequency Hopping Adaptively Equalized TDM (CFHATDM) or Multiple Carrier Modulation (MCM).

In accordance with still another aspect of the present invention, a single geostationary satellite transmits downlink signals which can be received by radio receivers in the LOS of the satellite signal, as well as by terrestrial repeaters. Each terrestrial repeater is configured to recover the digital baseband signal from the satellite signal and modulate the signal using multicarrier modulation (MCM) for retransmission toward radio receivers. Radio receivers are configured to receive both a quadrature phase shift keyed (QPSK) modulated TDM bit stream, as well as an MCM stream. Radio receivers are programmed to select a broadcast channel demodulated from the TDM bit stream and the MCM bit stream, and to select the broadcast channel recovered with the least errors using a diversity combiner.

In accordance with still yet another aspect of the present invention, a DBS is provided which comprises two geostationary satellites in combination with a network of terrestrial repeaters. The terrestrial repeaters are configured to process satellite downlink signals to achieve the baseband satellite signal and to modulate the signal using MCM. Radio receivers are configured to implement a diversity decision logic to select from among three diversity signals, including the two satellite signals and the MCM signal. Each radio receiver employs maximum likelihood combining of two LOS

satellite signals with switch combining between the terrestrial re-radiated signal, or MCM signal, and the output of the maximum likelihood combiner.

In accordance with another aspect of the present invention, a broadcast channel may be selected from the three diversity signals by using maximum likelihood combining of all three signals, that is, early and late LOS satellite signals and the MCM signal from the terrestrial repeater.

Brief Description of the Drawings

These and other features and advantages of the present invention will be more readily comprehended from the following detailed description when read in connection with the appended drawings, which form a part of this original disclosure, and wherein:

Fig. 1 depicts a digital broadcast system for transmitting satellite signals and terrestrial signals in accordance with an embodiment of the present invention;

Fig. 2 is a diagram of a digital broadcast system comprising a satellite and a terrestrial repeater in accordance with an embodiment of the present invention;

Fig. 3 is a schematic block diagram illustrating a generation of a multicarrier modulated (MCM) signal in accordance with an embodiment of the present invention;

Fig. 4 is a schematic block diagram depicting a radio receiver arm configured to demodulate MCM signals in accordance with an embodiment of the present invention;

Fig. 5 is a block diagram illustrating MCM signal demodulation in accordance with an embodiment of the present invention;

Fig. 6 is a schematic block diagram depicting a radio receiver arm configured to demodulate time division multiplexed (TDM) signals in accordance with an embodiment of the present invention;

Fig. 7 is a block diagram illustrating QPSK TDM signal demodulation in accordance with an embodiment of the present invention;

Figs. 8 and 9 are schematic block diagrams illustrating respective embodiments of the present invention for diversity combining in a radio receiver;

Fig. 10 illustrates a system of combining three diversity signals using a maximum likelihood decision unit in accordance with an embodiment of the present invention;

Fig. 11 is a schematic block diagram illustrating TDM signal demultiplexing in

accordance with an embodiment of the present invention;

Fig. 12 illustrates a system of combining bit streams recovered at a radio receiver using a maximum likelihood decision unit on a first satellite signal and a delayed second satellite signal and then a diversity combiner for terrestrial repeater signal and the output of the maximum likelihood decision unit in accordance with an embodiment of the present invention;

Fig. 13 illustrates an arrangement for indoor reception of a broadcast signal in accordance with an embodiment of the present invention; and

Fig. 14 illustrates an arrangement for terrestrial repeaters along a path in accordance with an embodiment of the present invention.

Detailed Description of the Preferred Embodiments

Fig. 1 depicts a digital broadcast system (DBS) 10 comprising at least one geostationary satellite 12 for line of sight (LOS) satellite signal reception at radio receivers indicated generally at 14. Another geostationary satellite 16 at a different orbital position can be provided for time and/or spatial diversity purposes as discussed below in connection with Figs. 6 and 7. The system 10 further comprises at least one terrestrial repeater 18 for retransmission of satellite signals in geographic areas 20 where LOS reception is obscured by tall buildings, hills and other obstructions. The radio receiver 14 is preferably configured for dual-mode operation to receive both satellite signals and terrestrial signals and to select one of the signals as the receiver output.

As stated previously, the present invention relates to a DBS 10 for optimized static, portable and mobile radio reception. In accordance with the present invention, the DBS 10 combines line-of-sight (LOS) reception of satellite waveforms that are optimized for satellite delivery with re-radiation of the LOS signal from the satellite 12 or 16 via one or more terrestrial repeaters 18. The terrestrial repeaters 18 use other waveforms which are optimized for terrestrial delivery where blockage of the satellite LOS signal occurs. LOS signal blockage caused by buildings, bridges, trees and other obstructions typically occurs in urban centers and suburban areas. Waveforms particularly suitable for LOS satellite transmission are Time Division Multiplex (TDM) and Code Division Multiple Access (CDMA). Multipath-tolerant waveforms

particularly suitable for overcoming terrestrial multipath interference encountered in blocked urban areas are CDMA, Adaptive Equalized TDM (AETDM), Coherent Frequency Hopping Adaptively Equalized TDM (CFHATDM) and Multiple Carrier Modulation (MCM).

Frequency hopping is described in U.S. Patent No. 5,283,780, to Schuchman et al, which is hereby incorporated herein by reference. When a terrestrial repeater 18 employs AETDM, radio receivers 14 are provided with an equalizer (not shown). For AETDM, a TDM bit stream is received from the satellite 12 or 16. The bit stream is converted into a new TDM bit stream into which training sequences are inserted by a process called puncturing. Puncturing replaces a small fraction of the TDM data bits with the training sequences. The number of bits punctured is so small that the errors thereby produced are correctable at the receiver by forward error correction. The new TDM bit stream is QPSK-modulated by the repeater onto a radio frequency (RF) carrier that is transmitted at high power into the multipath environment of a central city business district, for example. This transmitted signal is received by a receiver 14 equipped with an adaptive time domain equalizer. By using the training sequences, it can adjust the taps of an inverse multipath processor to cause the various multipath arrival components to add constructively. The signal thus reconstructed is next processed to recover the bits of the TDM stream with high accuracy. The forward error correction available in the receiver 14 corrects both the errors introduced by the puncturing and those caused by thermal noise and receiver impairments.

In accordance with another aspect of the present invention, the combination of a satellite-efficient LOS waveform and terrestrial multipath interference-tolerant waveform in a DBS system is the optimum means for achieving high availability reception by mobile radios, static radios and portable radios in urban areas, suburban areas and in rural areas. For example, in accordance with an embodiment of the present invention illustrated in Figs. 2-9, an MCM signal is sent from a network of terrestrial repeaters 18 deployed to cover a blocked area with high reception availability. The signaling techniques described in connection with the present invention are applicable over the electromagnetic wave frequency range from 200 to 3000 MHz to facilitate the combination of LOS satellite radiation with terrestrial re-radiation of the signal received

from the satellite 12 or 16.

Optimal satellite waveforms permit very efficient transformation of solar power, which is collected by the solar arrays of the satellites 12 and 16 into radiated radio frequency power. These waveforms are characterized by a low peak-to-average power ratio (i.e., crest factor), thereby permitting operation of high power amplifiers that feed the satellite earth-pointing antennas at or near the maximum power output and therefore the most efficient power output. A TDM waveform is particularly useful for permitting operation within a few tenths of a dB of maximum power output. A CDMA waveform that uses properly selected codes allows operation at approximately 2 to 4 dB below maximum power output. Because the MCM waveform is composed of the sum of hundreds of phase modulated sinusoids, as described below with reference to Fig. 3, the MCM waveform inherently possesses a high peak-to-average ratio. Consequently, a MCM waveform encounters significantly greater amplitude and phase intermodulation distortion in the satellite's high power amplifier. To achieve acceptable reception by an LOS satellite receiver, a MCM waveform is backed in the high power amplifier and allocated a receiver implementation impairment of at least 6 dB on the down-link budget, as compared with a quadrature phase shift keying (QPSK) TDM waveform. This translates to a 4-to-1 reduction in satellite power conversion, rendering the MCM waveform an unsuitable choice for satellite LOS delivery on a DBS 10. Regarding the AETDM and CFHATDM waveforms, these waveforms are specifically designated to combat terrestrial multipath and are not intended for, nor are they efficient, for satellite LOS delivery.

Regarding terrestrial reinforcement by re-radiation of the satellite LOS signal from a terrestrial repeater, for example, a TDM waveform is not suitable because its reception is severely impaired by multipath effects. Furthermore, some proposed systems which use CDMA waveforms for reinforcement repeat the same program signal using one CDMA channel code for LOS satellite delivery and another CDMA channel code for terrestrial re-radiated delivery on carriers that occupy the same frequency bandwidth. Reception is achieved by means of adaptive rake receivers. These proposed CDMA systems are disadvantageous because an annulus zone occurs in which reception is not possible between the region where the reinforcement signal can be received and

the region where the satellite LOS signal can be received. Receivers 14 in the annulus are not able to receive the terrestrial re-radiated signal because the signal power level falls below a receiver threshold for that signal. These receivers 14 are also not able to receive the satellite LOS signal because there remains sufficient re-radiated signal to jam LOS satellite reception. Thus, these receivers 14 in the annulus must move far enough away from the zone of re-radiation to decrease the re-radiated signal power to below the threshold of jamming; otherwise, LOS satellite reception is not possible.

In accordance with one embodiment of the present invention, the CDMA waveform is adapted to make possible its use for simultaneous delivery via satellite LOS and via terrestrial re-radiation. The CDMA channel codes are assigned for each delivery to different RF carriers. The orthogonality thereby created permits the two signals (i.e., the satellite LOS signal and the terrestrial repeater signal) to be separated by RF/IF filtering in the radio receiver.

The identification of workable and unworkable waveform combinations for accomplishing terrestrial reinforcement of satellite LOS reception in accordance with the present invention are listed in the TABLE 1. More than one type of modulation or signal formatting method can be used with the satellite signal, as well as with the terrestrial repeater signal.

TABLE 1

Satellite Waveform	Reinforcement Waveform	Recommended	Not Recommended	RF Carrier Spectra Are:
TDM	TDM		X	Same or Different
TDM	AETDM	X		Same or Different
TDM	MCM	X		Different
TDM	CFHATDM	X		Different
TDM	CDMA	X		Different
CDMA	CDMA	X		Different
CDMA	AETDM	X		Different
CDMA	CHFATDM	X		Different
CDMA	MCM	X		Different
CDMA	ANY		X	Same
AETDM	ANY		X	Same or Different
CFHATDM	ANY		X	Same of Different
MCM	ANY		X	Same or Different

AETDM waveforms can be satisfactorily implemented and operated in multipath environments characterized by signal propagation delays as long as 20 microseconds (μs). Care must be exercised to ensure that signal arrivals from distant repeaters 18 do not exceed this bound. The adaptively equalized re-radiated waveform can be received by radio receivers 14 designed to use the parent non-equalized TDM waveform when the former does not exhibit severe multipath. This compatibility prevents obsolescence of direct LOS non-equalized TDM radios when the AETDM re-radiation is turned on.

The CFHATDM waveform can be satisfactorily implemented and operated in multipath environments characterized by delays as long as 65 μs. Care must be exercised to ensure that signal arrivals from distant repeaters 18 do not exceed this bound. The waveform cannot be received by radio receivers 14 designed to use the parent non-equalized TDM waveform.

The MCM waveform can be satisfactorily implemented and operated in multipath environments characterized by delays as long as 65 μs. The maximum delay is affected by the guard time assignment given to the waveform's periodic symbol period assignment. Care must be exercised to ensure that signal arrivals from distant repeaters 18 do not exceed this bound. The waveform cannot be received by radio receivers 14 designed to use the parent non-equalized TDM waveform.

The CDMA waveform can be satisfactorily implemented and operated in multipath environments characterized by delays determined by the span of the time delays implemented in the rake paths at the receivers 14. Care must be exercised to ensure that all signal arrivals from distant repeaters 18, multipath reflections and different satellites do not exceed this bound. The waveform cannot be received by radio receivers 14 designed to use the parent non-equalized TDM waveform.

The satellite signals can be transmitted from one satellite 12 or 16 or from two satellites 12 and 16. Use of two geostationary satellites 12 and 16 sufficiently separated in their orbits creates diversity in the LOS elevation and azimuth angles to enhance signal reception availability. Also, time diversity achieved by repeating a satellite signal from a single satellite 12 or 16, or by transmitting a signal from two satellites 12 and 16 with the properly selected time difference, further enhances the reception availability.

In accordance with a preferred embodiment of the present invention, a waveform comprising multiple channel TDM with QPSK, Offset QPSK, Differential QPSK, Differentially Coded QPSK, or Minimum Shift Keyed (MSK) modulation is used for the transmission of signals from a satellite for LOS reception by a radio receiver 14. Terrestrial re-radiation is preferably implemented using an MCM waveform designed to carry a TDM bit stream of a capacity of up to 3.68 Mbit/s. MCM is preferably implemented which creates between 400 and 1200 multiple carriers by means of an Inverse Fast Fourier Transform as described below in connection with Fig. 3, resulting in a symbol period between 200 and 300 μs. A guard interval of between 55 to 65 microseconds is included in each symbol period. The MCM waveform is designed to accommodate Doppler carrier frequency shifts among multipath components occurring simultaneously. Puncturing is preferably used to eliminate bits or pairs of bits from the TDM bit stream to reduce the rate to a value of between 70% to 80% of the 3.68 Mbit/s rate. A special symbol is inserted between each of a selected number of FFT-generated symbols periods to provide a means to recover symbol period timing and carrier frequency synchronization . In the receiver 14, a Viterbi soft decision trellis decoder is preferably implemented to re-establish the bits or bit pairs punctured at the repeater 18, as well as all other bits transmitted, by use of an erasure technique. In this technique, the decoder simply ignores the bits in locations known to have been punctured at the repeater 18.

TDM carrier satellite delivery of the DBS 10 is discussed in U.S. patent application Serial No. 08/971,049, filed November 14, 1997, the entire subject matter of which is hereby incorporated herein by reference for all purposes. Briefly, with reference to Fig. 2, the broadcast segment 22 preferably includes encoding of a broadcast channel into a 3.68 Megabits per second (Mbps) time division multiplex (TDM) bit stream, as indicated in block 26. The TDM bit stream comprises 96 16 kilobits per second (kbps) prime rate channels and additional information for synchronization, demultiplexing, broadcast channel control and services. Broadcast channel encoding preferably involves MPEG audio coding, forward error correction (FEC) and multiplexing. The resulting TDM bit stream is modulated using quadrature phase shift keying (QPSK) modulation, as shown in block 28, prior to transmission via a satellite

uplink 30.

TDM satellite delivery achieves the greatest satellite on-board payload efficiency possible in terms of the conversion of solar power to electromagnetic wave power. This is because single TDM carrier per tube operation permits each satellite traveling wave tube to operate at its saturated power output, which is its most efficient operating point. The TDM carrier in a typical application is designed to deliver 96 prime bit rate increments, each bearing 16 kbit/s, to small, economical radio receivers 14 located in the beams of the satellite 12 or 16. From one to eight prime rate increments are grouped to constitute a broadcast channel. A broadcast channel can be divided into a number of service channels for delivery of audio, video, data and multimedia.

The power density delivered to the earth by TDM carriers from satellites 12 and 16 can made very high and hence provide excellent LOS reception by radio receivers 14 in automobiles and trucks when traveling on open highways in the country side and in suburban areas. However, in urban areas where tall buildings abound, or in forests where tall towering damp foliage trees abound, LOS reception is blocked, thus inhibiting suitable operation of the receiver 14 for LOS reception. Attempting to overcome these conditions by raising the satellite power is both excessively expensive and technically impractical. Accordingly, a more practical alternative is to augment the direct LOS satellite reception by adding a network of terrestrial repeaters 18.

Concerning the nature of the blockage of LOS reception consider the following. Locations directly beneath the satellite 12 or 16 (i.e., the sub-satellite point) inherently have the highest elevation angles, while locations that depart from the sub-satellite point inherently have decreasing elevation angles and an increase of the earth center angle subtended between the sub-satellite location and the reception location. Receivers 14 at locations that are near the sub-satellite point are permitted virtually unblocked LOS reception and the need for terrestrial reinforcement is minimal. However, when the LOS elevation angle to the satellite becomes less than about 85 degrees, blockage by tall buildings (i.e., >30 m) becomes significant. Accordingly, terrestrial re-radiation for gap-filling is needed to achieve satisfactory coverage for mobile radio receivers. In areas where building heights are low (e.g., < 10 m), blockages are not significant until the LOS elevation angle is lower than 75 degrees. At the mid-latitude and high latitude

locations within the 6 degree beam width coverages of the satellites 12 and 16, terrestrial re-radiation of the TDM waveform is needed to achieve suitable mobile reception. Thus, fully satisfactory mobile reception requires a system that combines satellite LOS and terrestrial re-radiation of the satellite waveform.

The DBS 10 of the present invention re-radiates the LOS satellite signal from a multiplicity of terrestrial repeaters 18 which are judiciously spaced and deployed within the central part of a city, as well as in metropolitan areas and suburban areas, to achieve maximum coverage. This type of deployment is a recognized art for terrestrial digital audio broadcast (DAB) and cell telephone systems, and can be extended in accordance with the present invention to terrestrial re-radiation of the TDM satellite LOS signal. The deployment utilizes a mix of radiated power levels (EIRP) ranging from as little as 1 to 10 watts for short range fill-in repeaters 18 (out to 1 km radius) to as great as 100 to 10,000 watts for re-radiators or repeaters having wide area coverage (from 1 km to 10 km radius).

Two preferred embodiments for a DBS 10 having a satellite-LOS/terrestrial-re-radiation configuration are described below. The first embodiment involves one geostationary orbit (GSO) satellite 12 or 16 having a judiciously selected longitude along the GSO arc which operates in coordination with a network of the terrestrial repeaters 18. The second embodiment involves two satellites 12 and 16 having different judiciously spaced GSO longitudes to achieve space and time diversity.

The embodiment for a DBS 10 using one GSO satellite 12 with at least one terrestrial repeater 18 is shown in Fig. 2 for illustrative purposes. For each terrestrial repeater 18, the LOS satellite signal is received by an antenna 32 operating in conjunction with a radio receiver 34 to demodulate and recover the digital baseband signal from the signal radiated from the satellite 12. A delay block 35 delays the entire digital baseband signal by the amount of time diversity delay (if any) between transmissions from the satellites 12 and 16. The digital baseband signal is supplied to a terrestrial waveform modulator 36 that generates a waveform which is judiciously designed to make possible the recovery of the digital baseband signal after the waveform has been transmitted from the terrestrial repeater 18 and received by a radio receiver 14. The modulated waveform is then frequency translated to a carrier frequency and

amplified, as indicated by block 38. The terrestrial re-radiated waveform is specifically chosen to withstand the dynamic multipath encountered over the terrestrial path between the transmitter antenna 40 and the receiver 14. This multipath is caused by reflections and diffractions from and around obstacles such as buildings 44 and terrain and from troposphere wavebending and reflections.

The antenna 32 is designed to have high gain (> 10 dBi) toward the satellite 12, while achieving low gain in other directions such that the LOS signal is received with low interference and consequently very high quality (i.e. error rate < 10^{-9}). The demodulator and other reception elements in the receiver 34 are those designed for the LOS radio receivers 14 used in the DBS 10 and described in the aforementioned application Serial No. 08/971,049, filed November 14, 1997. The radio receivers 18 are designed to receive the 3.68 Mbit/s QPSK modulated TDM bit stream. As stated previously, the digital baseband is preferably a 3.68 Mbit/s digital waveform TDM bit stream that carries 96 16 kbit/s prime bit rate digital channels organized into broadcast channels, and side information needed to synchronize, demultiplex and control the broadcast channels and the services they bare. The terrestrial waveform modulator 36 and the waveform that it generates is designed to allow reception unimpeded by the multipath vagaries indicated at 42 of the terrestrial path as described previously. Possible multipath-tolerant waveforms are adaptive equalized TDM, adaptive equalized multiple carrier frequency hoppers with adaptive equalization, Fast Fourier Transform multiple carrier modulation and CDMA with rake receivers. The repeater 18 is equipped to assemble the multipath-tolerant waveform, to frequency convert the waveform to the desired re-radiator transmitter RF frequency at the selected power level via the RF translator 38, and to radiate the waveform from antenna 40. The antenna 40 is preferably configured to provide omni-directional or sector directional propagation in the horizontal plane and high directive toward the horizon. The net antenna gain is expected to range from 10 to 16 dBi. The antenna 40 can be located on top of a building and/or on a tower at a desired height. As previously mentioned, the radiated power level can range from 1 to 10,000 watts of EIRP depending on the application.

A particularly desirable multipath-tolerant re-radiated waveform uses

multicarrier modulation (MCM). The manner in which the waveform is generated is shown in Fig. 3. A digital stream such as the 3.68 Mbit/s TDM stream is time-domain-divided into a number of parallel paths (block 102), for example, 460 parallel paths with each parallel path carrying 8000 bits per second. The bits on each of these paths are paired into 2 bit symbols with one bit identified as the I (imaginary) component and the other as the Q (Real) component of a complex number. This creates a complex symbol rate of 4000 per second. These bits are fed as 460 parallel complex number frequency coefficient inputs to a Discrete Inverse Fourier Transform converter implemented using a 512 coefficient Inverse Fast Fourier Transform (IFFT) 104. It is well known in the current state of the art that the Fast Fourier Transform algorithm must operate with 2^n input and output coefficients where n is any integer. Thus, for $n = 9$, $2^9 = 512$. Since the number of coefficients is 460, the remaining 52 missing input coefficients are set equal to zero. This is done by assigning 23 zero-valued coefficients at each the uppermost and lower most IFFT inputs, thus leaving the 460 center coefficients assigned to non-zero values. The output 104 of the IFFT is a set of 460 QPSK-modulated, orthogonal sine coefficients which constitute 460 narrow band orthogonal carriers, each supporting a symbol rate of 4000 per second and consequently having a symbol period of 250 μs. No carriers appear at the output of the IFFT 104 for the coefficients that are set equal to zero.

The IFFT multicarrier output 104 is further processed to create a guard interval 105 for the set of 460 complex symbol narrow band orthogonal carriers (block 106). It is assumed that a fraction f of a symbol period Ts is to be allocated to guard time. To do this the symbol duration must be reduced to a value Ts = (1-f) Ts. For the example considered above Ts = 250 μs. If 25 % of the symbol time is to be allocated guard time, then f =0.25 and Ts = 187.5 μs. To do this, the symbol period output of the IFFT is stored in a memory every 250 μs and then played back in 187.5 μs. To fill the 250 μs symbol interval, the first samples of the IFFT output are again played back during the 62.5 μs guard interval. This procedure causes an increase in the bandwidth of the multicarrier output by a multiplication of (1-f)-1. Thus, the bandwidth needed for the multicarrier modulator output is multiplied by 1.33 to a value of 4000 x 460 x 1.33 = 2.453 MHz.

Finally, to complete the multicarrier modulator processing, a symbol 106 containing a synchronization symbol is introduced periodically, as indicated by block 108. This is done to provide the means for synchronizing a sampling window of 187.5 μs duration at the receiver 14 to the center of the group of multipath arrivals every 250 μs. Also, a phase reference symbol for differential reference coding of the symbol information is also added periodically. The synchronization and phase reference symbols are preferably introduced every 20 to 100 symbol periods depending on the design requirements.

An additional feature of the modulation design is to puncture the TDM digital bit stream, as indicated by phantom block 110, at the input to the modulator 36 to reduce the final bandwidth of the multicarrier waveform. Puncturing means selective, sparse elimination of real data bits from the data stream applied at the input to the IFFT 104. This can be done for a fraction of the bits of the stream in anticipation that the forward error correction scheme applied at the receiver 14 will simply treat the punctured bits as errors and correct them. This has the consequence of increasing the signal to noise ratio (E_b/N_o) for a desired reception BER objective by 1 to 3 dB, depending on the fraction of bits removed by the puncturing. The design for the punctured waveform proportionately reduces the bandwidth of the multicarrier modulation. For example, if the bit rate of the TDM stream is reduced by 75% , the bandwidth will also be reduced by 75%. For the example previously given, the bit rate is reduced to 2.76 Mbit/s and the multicarrier bandwidth to 1.84 MHz. Such bandwidth compression can be necessary in applications where the available frequency spectrum would otherwise be insufficient to carry the desired capacity.

Further details concerning the preferred multicarrier modulation techniques used herein can be found in International Application Nos. PCT/EP98/02167, PCT/EP98/02168, PCT/EP98/02169, PCT/EP98/02170 and PCT/EP98/02184, all filed on April 14, 1998 by Fraunhofer-Gesellschaft zur Förderung.

It is to be understood that the terrestrial repeater described with reference to Figs. 2 and 3 is used to recover a TDM satellite downlink signal, and to demodulate and reformat the TDM signal via baseband processing into a different waveform using, for example, CDMA, AETDM, MCM or CHFATDM. It is to be understood, however,

that the DBS 10 can comprise terrestrial repeaters 18 which are co-channel or non-co-channel repeaters. For example, terrestrial repeaters 18 can be provided which are co-channel gap-fillers which merely amplify and repeat a received satellite signal on the same carrier as the satellite signal. Alternatively, terrestrial repeaters can be provided which are non-co-channel gap-fillers which amplify and repeat a satellite signal on a different carrier frequency via frequency translation. In either case, baseband processing of the satellite signal is not performed at the repeater. These types of gap-fillers can be used, for example, indoors (Fig. 10) or along a roadway (Fig. 11).

At a radio receiver 14 shown in Fig. 4, the multicarrier modulated RF waveform is received by the antenna 201 operating in conjunction with a low noise RF front end 202, mixer 203, local oscillator 204, first intermediate frequency (IF) 205, second mixer 206, second local oscillator 207, second IF 208 to recover the multicarrier modulated carrier. A multicarrier demodulator 209 recovers the TDM digital baseband signal. To demodulate the multicarrier waveform, the received modulated signal is digitally sampled by a sampler 211, as shown in Fig. 5, at a rate equal to two of four times the bandwidth of the modulation. These samples are taken during a window of 187.5 μs duration which is optimally centered on the cluster of time dispersed multipath arrivals during each symbol period once every 250 μs. The samples are rate down converted by a buffer memory 212 to expand them to the 460 complex time domain samples in the original 250 μs duration window. These samples are then processed by an 512 coefficient FFT 213 to recover the bits of the TDM bit stream. The receiver 14 next synchronizes to the TDM masterframe frame preamble via unit 214, demultiplexes and aligns the prime rate bits via unit 215 and then recovers the bits of a selected broadcast channel via unit 216. These bits are then forward error corrected using concatenation of a soft decision Viterbi decoder 217, a de-interleaver 218, followed by a Reed Solomon decoder 219, to recover the broadcast channel (BC). This recovered BC is supplied as one input to a decision/combiner unit 240, as described below in connection with Fig. 6.

For a two-arm receiver 14, as depicted in Fig. 6, the MCM signal is received as described with reference to Fig. 4. The QPSK modulated satellite TDM RF waveform is also received by the antenna 201 operating in conjunction with the low noise RF

front end 202, a mixer 220, a local oscillator 221, a first IF 222, a second mixer 223, a second local oscillator 224, and a second IF 225, to recover the QPSK-modulated TDM carrier. As shown in Fig. 7, a QPSK TDM carrier demodulator 226 comprises a QPSK demodulator 227 which recovers the TDM digital baseband. The receiver 14 next synchronizes to the TDM masterframe frame preamble 228, demultiplexes and aligns the prime rate bits 229 and then recovers the bits of a selected broadcast channel. These bits are then forward error corrected 230 using the concatenation of a soft decision Viterbi decoder 231, a de-interleaver 232, and a Reed Solomon decoder 232, to recover the broadcast channel. This recovered BC is supplied as a second input to the decision/combiner unit 240.

The diversity combiner 240 selects which of the two input BCs is to be submitted for further processing. It does this based on selecting that BC which is recovered with the least errors. Estimates of the error counts are available from the soft decision data supplied by the Viterbi decoders 217 and 231 or the Reed Solomon decoders 219 and 233. The decision is preferably made with a hysterisis logic which requires that several errors of difference exist before the decision is reversed. This process is needed to prevent chattering between the two BCs when the decisions are nearly equally likely. The broadcast channel selected by the diversity combiner 240 is next supplied to the appropriate source decoder 244 to recover the service(s).

The embodiment of the DBS 10 which uses two GSO satellites 12 and 16 with terrestrial repeater 18 is shown in Fig. 8. In this configuration, two satellites 12 and 16 are separated by between 30 degrees to 40 degrees longitude along the GSO circle. One satellite repeats a signal sent from a ground station, and the other satellite repeats the same signal sent from the same ground station but delays the signal as much as 5 to 10 seconds. The use of two satellites 12 and 16 separated in space results in elevation angle diversity in the LOS paths between a radio receiver 14 on the earth and each satellite 12 and 16. The time delay between the two satellite signal arrivals results in time diversity. Each of these types of diversity taken alone can significantly improve the availability of the LOS signal for a moving mobile receiver 14, and the improvement in availability is further significantly enhanced by both space and time diversity. Space and time diversity are particularly important when a mobile receiver 14 is traveling in a suburban

area or in a rural area where the LOS signal blockage is due to bridges, trees and low buildings. However, for central city and metropolitan areas, where tall buildings abound, terrestrial re-radiation of the signal is also supplied in accordance with the present invention to achieve acceptable total area coverage for mobile reception. Thus, this two-satellite diversity configuration operates essentially the same way as the single satellite configuration with regard to the diversity between direct LOS satellite reception and terrestrial re-radiated reception, but adds the time and space diversity provided by the two satellites. The signal from the early satellite is the one re-radiated by the terrestrial repeater 18. Choice of the early signal allows any delay encountered in the signal processing at the repeater 18 or the receiver 14 to be absorbed. The terrestrial re-radiation network is otherwise implemented in the same way as previously described for the single satellite configuration.

Another difference between the two-satellite system and the one-satellite system resides in the three-arm radio receiver 14. The receiver 14 introduces appropriate compensating delays via delay units 309 and 310 to achieve simultaneous signal reception among the three received signals and implement a diversity decision logic which selects among the three diversity signals. The delay unit 309 provides a time diversity delay to the early signal to compensate for the signal propagation differential between the early and late satellites 12 and 16. The delay unit 310 is preferably a vernier delay to allow fine compensation for signal alignment. The radio receiver diversity logic design is shown in Fig. 8. It incorporates a maximum likelihood combiner 240 for the Early and Late LOS satellite signals with a switched combiner 307 between the terrestrial re-radiated signal and the output of the maximum likelihood combiner 240. When both signals are degraded, maximum-likelihood combining can improve the quality of reception. The improvement can be as much as 3 dB in terms of threshold E_b/N_o when both signals are equally degraded.

The radio receiver 14 is equipped with two receiver chains 301 and 302 that individually receive and recover the TDM signals from the early and late satellites, respectively, and selects a desired broadcast channel from each. This is done for each received signal in the same manner as previously described for LOS satellite reception in Fig. 6. Next, the broadcast channel signal derived from the early satellite is delayed by a

delay unit 309 comprising a memory device to align it precisely, that is, symbol by symbol, with the symbols of the broadcast channel derived from the late satellite signal. This can be done by aligning the two broadcast channels relative to one another so as to cause coincidence of their service control header preamble correlation spikes. This coincidence is detected in a correlation comparitor unit in the delay unit 309. The next step is to use the maximum likelihood combiner 240 to combine the bits of the two broadcast channels, bit-by-bit, each bit expressed in soft decision form. The maximum likelihood combining coefficients are determined over 1 ms blocks of bits. Next, the output of the maximum likelihood combiner 240 is applied as one input to the switched combiner 307, with the other input coming from the terrestrial re-radiated signal receiver arm 308. The choice of which input is to be passed to the output is based on selecting that BC which is recovered with the least errors. In accordance with another embodiment of the present invention, one of the TDM signal receiver chains (e.g., receiver chain 302 for the late satellite TDM signal) can be maximum likelihood combined with the signal from the terrestrial re-radiated signal receiver arm 308, as shown in Fig. 9. Thus, the switched combiner 307 selects from between the output of the maximum likelihood combiner 240 and the other satellite signal receiver arm (e.g., arm 301), as shown in Fig. 9. The delay units 309 and 310 can be configured to store the entire recovered bit stream for delay purposes, which requires more buffering but simplifies combining. Alternatively, the delay units 309 and 310 can be configured to store only a portion of the recovered TDM bit stream; however, synchronization requirements for combining become more complicated.

With regard to switched combiner 307, estimates of the error counts are available from the soft decision data supplied by the Viterbi decoders 217 and 231 or the Reed Solomon decoders 219 and 233. The decision is made with a hysterisis logic which requires that several errors of difference exist before the decision is reversed. This process is prevents chattering between the two BCs when the decisions are nearly equally likely. Alternatively, a simple switching logic may be used in which the switch always favors the choice of the BC having the least errors. Hysterisis is used to prevent chattering. The latter implementation avoids the more complex maximum likelihood combining. Yet another alternative could be maximum likelihood combining of the

three input BCs (e.g., from receiver arms 301, 302 and 308), as shown in Fig. 10.

The diversity combiner shown in Fig. 10 combines three signals. Two are received from two spatially separated satellites 12 and 16, one broadcasting an early signal and the other broadcasting a late signal. The third signal is received from a terrestrial repeater 18 which rebroadcasts the early satellite signal. These signals are received by receiver arm 301 for the early satellite 12, receiver arm 302 for the late satellite 16 and receiver arm 308 for the early signal retransmitted by the repeater 18. The diversity combiner 312 combines the symbols in the three signals by maximum likelihood ratio combining. By this method, the samples of the symbol appearing at the output have the highest probability of representing the original transmitted symbol. To do this, the early satellite 12 and repeater 18 signals are delayed relative to the late satellite signal by delay units 309 and 310 to realign the individual symbols of the three signals causing them to be in time coincidence. Simple *a priori* adjustment of the delay units 309 and 310 suffices to coarsely align the output of the delay units 309 and 310 to within a TDM frame of 138 μs. Thus, fine alignment of the symbols to the master frame preamble (MFP) of a TDM frame is nonambiguous. To align the symbols of the three signals precisely, the MFPs for each signal stream are aligned by fine tuning the delay units 309 and 310 to within a small fraction of a symbol.

With continued reference to symbol combining in unit 312, the normalized variance σ_x^2 for the signal symbols, as contained in the background of noise, and uncorrelated multipath interference, is calculated from the observed samples. These variances are calculated for the early (E), late (L) and repeater 18 or gap-filler (G) signal symbols. The respective signal samples of the symbols for the early, late and gap-filler signals are then multiplexed by their variance ratios $(q_E)^{-1}$, $(q_L)^{-1}$ and $(q_G)^{-1}$, which are defined as follows:

$(q_E)^{-1}$ is the weighting factor associated with early symbol S_E
$(q_L)^{-1}$ is the weighting factor associated with early symbol S_L
$(q_G)^{-1}$ is the weighting factor associated with early symbol S_G

The weighting factors are inversely proportional to the estimated variance and are

normalized such that

$$q_E + q_L + q_G = 1$$
$$q_E = \sigma_E^2/(\sigma_E^2 + \sigma_L^2 + \sigma_G^2)$$
$$q_L = \sigma_L^2/(\sigma_E^2 + \sigma_L^2 + \sigma_G^2)$$
$$q_G = \sigma_G^2/(\sigma_E^2 + \sigma_L^2 + \sigma_G^2)$$

Their sum constitutes the maximum likelihood ratio combined symbols. These are then passed on to the time demultiplexer/FEC decoder/BC remultiplexer unit 250 (Fig. 11), the components of which have previously been described above in connection with Fig. 5, to recover the maximum likelihood ratio combined symbols by decision processing.

The diversity combiner shown in Fig. 12 first combines signals received from two satellites 12 and 16, one broadcasting an early signal and the other broadcasting a late signal. The result of this is next combined by minimum bit error decision with reception of the early signal that has been retransmitted by a gap-filler repeater 18 located on the ground. The individual signals are received by the receiver arm 301 for the early satellite, the receiver arm 302 for the late satellite and the receiver arm 308 for the early signal retransmitted by the gap-filler repeater 18. The maximum likelihood ratio diversity combiner 412 combines the symbols of the early and late satellite signals in the same manner described above in connection with combiner 312 in Fig. 10 for three signals. By this method, the final symbol appearing at the output of unit 412 has the highest probability of representing the original transmitted symbol .

The result from unit 412 is next combined with that from the terrestrial repeater 18 by minimum BER select unit 417. Within the unit 417, there are preferably two units 250 that make FEC-decoded symbol decisions for an entire broadcast channel frame of the signals applied at their inputs. One unit 250 makes its decisions on the output from maximum likelihood decision unit 412, and the other unit 250 from the signal received from the terrestrial repeater 18. These decisions also provide the number of errors made with each decision observed over the duration of a broadcast frame. A BER compare unit 414 operates in conjunction with a minimum BER select unit 417 to select the symbols of that broadcast frame with the least error, as determined from

inputs from Viterbi FEC units 217 and 231. To implement the necessary delay operations, the early and gap-filler signals are delayed by delay units 309 and 310 to realign their individual symbols to be in symbol time coincidence with the symbols received from the late satellite. The delay alignment method used here is the same as that described for the implementation of Fig. 10.

In accordance with another aspect of the present invention, an indoor re-radiation system 450 is provided which is illustrated in Fig. 13. Since LOS reception of a satellite signal at a radio receiver located inside a building or other structure is generally not available, unless the radio receiver 14 is located at a window in LOS of the satellite 12 or 16, indoor reinforcement of satellite signals for more complete coverage.

As shown in Fig. 13, an antenna 452 can be located externally with respect to a building so as to achieve LOS reception of satellite signals. A tuned RF front-end unit 454 is connected to the antenna 452 and is preferably configured to select the portion of the RF spectrum that contains the essential frequency content of the satellite signal and by doing so with very low added noise. An interconnecting cable 456 is provided to supply the signal at the output of the tuned RF front-end unit 454 to an amplifier 458. The amplifier 458 is connected to a re-radiating antenna 460 located within the building.

The amplifier 458 is configured to increase the power of the satellite signal to a level that, when re-radiated, by the antenna 460, is sufficient to permit satisfactory indoor reception for a radio receiver. The power level radiated from the antenna 460 is sufficiently high to achieve satisfactory indoor reception at locations which are not in the LOS of the satellite, but not so high as to cause instability by signals returned by the path between the indoor antenna 460 and one or more of the receiving antennas 452. Thus, high isolation (i.e., on the order of 70-80 dB) is preferred between the indoor antenna 466 and the outdoor antenna 452.

Reception areas will be present (e.g., through windows or other openings to the building or structure) where indoor re-radiated signals combine with an outdoor signal transmitted directly from the satellite. To assure that the combination of these signals does not occur in an manner which is destructive to signal content, the time delay between an outdoor signal and an indoor signal in the region of combination is preferably less than a fraction of the symbol width of the signal being transmitted. For

example, for a symbol width of approximately 540 nanoseconds, a time delay between 50 and 100 nanoseconds can be tolerated. The time delay is generally due to the time required for a signal to travel the path comprising the outdoor antenna 452, the cable (where signals generally travel at two-thirds the speed of light), and onward to the indoor antenna 460. Another delay occurs as the signal travels from the indoor antenna 460 to the radio receiver 14 in an area covered by the indoor antenna. This time delay is preferably only 20% of the symbol width, that is, not more than 100 nanoseconds for a system in which the symbol width is 540 nanoseconds.

The purpose of a terrestrial repeater is to repeat a signal received from the satellite into areas where the signal is otherwise blocked. A multiplicity of these terrestrial repeaters 18 may be placed along a roadway or other path at a height h and separated by distances d, as shown in Fig. 14. The heights and separation distances between the terrestrial repeaters need not be equal. A terrestrial repeater 18 comprises a receive antenna 462 that is pointed at the satellite 12 or 16, a receiver (not shown) that recovers the signal and amplifies it with a gain that is sufficient to drive a transmit antenna 464 such as to a power flux density in the path below which is comparative to that normally expected from the satellite. The transmit antenna 464 is shielded so as to prevent the transmitted signal from reaching the terrestrial repeater receive antenna 462 at a level sufficient to create instability. The transmit antenna 464 radiates its power over an aperture of length L sufficient to cause path length diversity over several wavelengths between the transmitter 464 and the vehicle's receive antenna at the carrier frequency.

As a vehicle drives along the path, the radio receiver 14 therein receives signals coming from more than one terrestrial repeater 18. For example, in position A, a vehicle is nearest to terrestrial repeater 18b and that terrestrial repeater's signal dominates and be responsible for reception. Signals from terrestrial repeaters 18a and 18b are low because of distance and antenna pattern and cause little interference. If the vehicle is at position B, the radio receiver 14 therein receives signals from both terrestrial repeaters 18c and 18d. Since the distances are nearly equal, and assuming that the time difference between signals radiated from terrestrial repeaters 3 and 4 is adjusted to zero, the time difference of arrival between the signals received at the vehicle are

sufficiently small so as to cause constructive reinforcement. By proper choice of the distances h and d in relationship with the symbol period of the digital signal being received, this condition can be achieved.

It is important to cause diversity in the signals that arrive at the vehicle from the different terrestrial repeaters. If this is not done, then the signals from two terrestrial repeaters, as would be received in the location B, would combine alternately in-phase and out-of-phase and phases in between. When they are in phase, the signals reinforce, and when out-of-phase the signals cancel. When signal cancellation occurs, the signal is completely lost. In addition, the resulting carrier phase of the signal created by addition of the terrestrial repeater carriers rotates at a rate equal to a nearly monochromatic Doppler difference, making it difficult to recover the QPSK modulation. The spread in arrival times caused by the diversity transmission resulting from distribution of the transmitted signal over the aperture L, or over an equivalent time difference of L/C where C = speed of light, eliminates the amplitude cancellation and provides the possibility of correcting the impact of the phase rotation by application of adaptive equalization techniques. This applied to all vehicle locations between locations A and B.

An example of the proper choice of distances in relationship to symbol period is seen by considering a signal having a symbol period on the order of 540 to 550 nanoseconds. The spacing d and height h is selected so as to cause the time delay in transversing the slant distance $(d^2 + h^2)^{1/2}$ to cause a delay of no greater than a quarter of a symbol period. In this example, the slant distance is 550/d = 137.5 ft. One nanosecond is equivalent to one foot at the speed of light. Thus, if the height is 20 feet, the distance d is 180 feet. The height h is preferably relatively small when compared to distance d so as to cause the difference in distance between the vehicle and each terrestrial repeater 18 to change by an amount sufficient to assure that the signal level from any one terrestrial repeater is attenuated by 10 dB or more compared to that from a terrestrial repeater immediately overhead. The length L is preferably between 5 to 10 feet to provide sufficient path length diversity at L-band frequencies. If an equalizer unit is incorporated in the vehicle's mobile receiver 14, the time difference in arrival can be extended to several symbols, thus increasing the distance between the terrestrial

repeaters to over 1000 feet. An equivalent time difference would be to transmit the signal several times from the same source over a spread not exceeding 5-10 nanoseconds.

While various embodiments have been chosen to illustrate the invention, it will be understood by those skilled in the art that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims.

What is Claimed Is:

1. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and

at least one terrestrial repeater for receiving said satellite signal and generating and transmitting at least one terrestrial signal from said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

2. A system as claimed in claim 1, wherein said satellite is operable to modulate said broadcast program in accordance with at least one of time division multiplexing and code division multiplexing, and said terrestrial repeater is operable to modulate said terrestrial signal using at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptively equalized time division multiplexing, multicarrier modulation and code division multiplexing.

3. A system as claimed in claim 1, wherein said terrestrial repeater is operable to modulate said terrestrial signal using multicarrier modulation.

4. A system as claimed in claim 3, wherein said terrestrial repeater is operable to receive said satellite signal and to demodulate said satellite signal into a baseband signal prior to modulating said baseband signal using multicarrier modulation.

5. A system as claimed in claim 1, wherein said satellite signal is assigned a first code division multiple access channel code and said terrestrial signal is assigned a second code division multiple access channel code.

6. A system as claimed in claim 1, further comprising a second satellite, said second satellite being operable to receive said broadcast program from said earth station and to

transmit at least one second satellite signal comprising said at least a portion of said broadcast program to said radio receivers on said first carrier frequency and delayed a predetermined period of time with respect to the transmission of the other said satellite signal.

7. A terrestrial repeater for re-radiating broadcast signals to radio receivers comprising:

a receiver for receiving said broadcast signals; and

a terrestrial waveform modulator for generating terrestrial signals comprising said broadcast signals, said terrestrial signals being modulated by said terrestrial waveform modulator in accordance with multicarrier modulation.

8. A terrestrial repeater as claimed in claim 7, wherein said broadcast signals are transmitted to said radio receivers from a satellite using a first carrier frequency, said terrestrial waveform modulator being operable to transmit said terrestrial signals to said radio receivers using a second carrier frequency.

9. A terrestrial repeater as claimed in claim 7, wherein said terrestrial waveform modulator comprises:

a time division demultiplexer for demultiplexing said broadcast signals from a serial time division multiplexed bit stream into a plurality of parallel bit streams; and

an inverse fast Fourier transform device for generating a digital analog signal comprising a plurality of discrete Fourier transform coefficients.

10. A method of converting a time division multiplexed bit stream into a plurality of multicarrier modulated signals at a terrestrial repeater comprising the steps of:

receiving said time division multiplexed bit stream from a satellite;

dividing said time division multiplexed bit stream into a plurality of parallel bit paths;

representing each of a predetermined number of bits in each of said plurality of bit paths as a symbol comprising an imaginary component and a real component;

providing said symbols to parallel inputs of an inverse Fourier transform converter as complex number frequency coefficient inputs to generate outputs which are narrow band, orthogonal carriers; and

re-radiating said narrow band, orthogonal carriers.

11. A method as claimed in claim 10, further comprising the step of generating a guard interval for said carriers.

12. A method as claimed in claim 11, wherein said generating step comprises the steps of:

allocating a fraction of the symbol period corresponding to the duration of each of said symbols to guard time; and

reducing the duration of each of said symbols.

13. A method as claimed in claim 12, wherein said reducing step comprises the steps of:

storing said outputs of said inverse Fourier transform converter in a memory device every said symbol period; and

reading from said memory device after each said fraction of said symbol period has elapsed.

14. A method as claimed in claim 11, wherein said generating step further comprises the step of filling said guard interval with a subset of said outputs of said inverse Fourier transform.

15. A method as claimed in claim 10, further comprising the step of inserting a synchronization symbol every predetermined number of said symbol periods to synchronize a sampling window corresponding to said fraction of said symbol period with respect to said carriers every said symbol period at a receiver for said plurality of multicarrier modulated signals.

16. A method as claimed in claim 10, further comprising the step of puncturing said time division multiplexed bit stream to reduce the total bandwidth associated with said carriers.

17. A method as claimed in claim 16, wherein said puncturing step comprises the step of selectively eliminating bits from said time division multiplexed bit stream prior to providing said symbols to parallel inputs of an inverse Fourier transform converter.

18. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a first satellite configured to receive said broadcast program from said earth station and to transmit at least one first satellite signal comprising at least a portion of said broadcast program to said radio receivers, said first satellite signal being formatted in accordance with at least one of time division multiplexing and code division multiplexing; and

at least one terrestrial repeater configured to receive said first satellite signal and to generate and transmit at least one terrestrial signal from said first satellite signal comprising at least a portion of said broadcast program, said terrestrial signal being formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

19. A digital broadcasting system as claimed in claim 18, wherein said first satellite signal is transmitted to said radio receivers using a first carrier frequency, and said at last one terrestrial signal is transmitted to said radio receivers using a second carrier frequency.

20. A digital broadcasting system as claimed in claim 18, wherein at least one of said radio receivers is configured to receive said first satellite signal and said terrestrial signal and comprises a diversity combiner to generate an output signal from said first satellite signal and said terrestrial signal.

21. A digital broadcasting system as claimed in claim 18, further comprising a second satellite configured to receive said broadcast program from said earth station and to transmit at least one second satellite signal comprising at least a portion of said broadcast program to said radio receivers, said second satellite signal being delayed with respect to said first satellite signal by a selected time delay, said second satellite signal being formatted in accordance with the corresponding at least one of time division multiplexing and code division multiplexing employed by said first satellite.

22. A digital broadcasting system as claimed in claim 21, wherein at least one of said radio receivers is configured to receive said first satellite signal, said second satellite signal and said terrestrial signal, to delay at least one of said first satellite signal and said terrestrial signal in accordance with said selected time delay, and to generate an output signal from first satellite signal, said second satellite signal and said terrestrial signal.

23. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner and a switched combiner, said radio receiver using said diversity combiner to perform maximum likelihood decision combining of said first satellite signal and said second satellite signals and said switch combiner to select between the output of said diversity combiner and said terrestrial signal depending on which of said output of said diversity combiner and said terrestrial signal comprises the least number of bit errors.

24. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner to perform maximum likelihood decision combining of said first satellite signal, said second satellite signals and said terrestrial signal.

25. A receiver for receiving a broadcast signal in a digital broadcasting system comprising:

a first receiver arm for receiving a first satellite signal transmitted from a first satellite on a first carrier frequency, said first satellite signal comprising at least a portion of said broadcast signal and being formatted in accordance with at least one of time

division multiplexing and code division multiplexing, said first receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal;

a second receiver arm for receiving a terrestrial signal transmitted on a second carrier frequency, said terrestrial signal comprising said at least a portion of said broadcast signal and being formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation, said second receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal; and

a combiner for generating an output signal from said first satellite signal and said terrestrial signal.

26. A receiver as claimed in claim 25, further comprising:

a third receiver arm for receiving a second satellite signal from a second satellite and delayed with respect to said first satellite signal in accordance with a selected time delay, said second satellite signal comprising at least a portion of said broadcast signal and being formatted in accordance with the corresponding at least one of time division multiplexing and code division multiplexing employed by said first satellite, said first receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal; and

a delay device for delaying said first satellite signal in accordance with said selected time delay, said combiner being operable to generate an output signal from said first satellite signal, said second satellite signal and said terrestrial signal.

27. A method of transmitting a broadcast program to radio receivers comprising the steps of:

formatting a broadcast signal for transmission to said radio receivers as a first signal in accordance with one of time division multiplexing and code division multiplexing;

transmitting said first signal to said radio receivers from a first satellite on a first carrier frequency;

formatting said broadcast signal for transmission to said radio receivers as a second signal in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation; and

transmitting said second signal to said radio receivers from a terrestrial repeater on a second carrier frequency.

28. A method as claimed in claim 27, wherein said formatting step for formatting said broadcast signal as said second signal comprises the steps of:

receiving said first signal at said terrestrial repeater; and

performing baseband processing of said first signal prior to formatting in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

29. A method as claimed in claim 28, further comprising the step of receiving said first signal and said second signal at one of said radio receivers.

30. A method as claimed in claim 29, further comprising the step of demodulating each of said first signal and said second signal to remove said respective formatting and to recover a first recovered broadcast signal and a second recovered broadcast signal, respectively.

31. A method as claimed in claim 30, further comprising the steps of generating an output broadcast signal from said first recovered broadcast signal and said second recovered broadcast signal.

32. A method as claimed in claim 31, wherein said generating step comprises the step of performing maximum likelihood combining of said first recovered broadcast signal and said second recovered broadcast signal.

33. A method as claimed in claim 27, further comprising the steps of:

formatting a broadcast signal for transmission to said radio receivers as a third signal in accordance with at least one of time division multiplexing and code division multiplexing;

transmitting said third signal to said radio receivers from a second satellite, said transmission being delayed with respect to said first signal by a predetermined period of time.

34. A method as claimed in claim 33, further comprising the steps of:

receiving said first signal, said second signal and said third signal at one of said radio receivers;

demodulating each of said first signal, said second signal and said third signal to remove said respective formatting and to recover a first recovered broadcast signal, a second recovered broadcast signal and a third recovered broadcast signal, respectively; and

generating an output broadcast signal from said first recovered broadcast signal, said second recovered broadcast signal and said third recovered broadcast signal.

35. An indoor reinforcement system for receiving a satellite signals transmitted in a digital broadcasting system using a radio receiver located indoors, comprising:

a line of sight antenna for receiving line of sight satellite signals;

a radio frequency front-end unit connected to said line of sight antenna for passing frequency spectrum comprising said satellite signal with low noise;

at least one indoor amplifier;

at least one cable for connecting said radio frequency front-end unit to said indoor amplifier; and

at least one indoor re-radiating antenna connected to said indoor amplifier, said indoor re-radiating antenna having a power level selected to be sufficiently high to achieve satisfactory indoor reception of said satellite signals at radio receivers at indoor locations where line of sight reception of said satellite signals is not possible and sufficiently low to prevent interference by said satellite signals transmitted between said line of sight antenna and said indoor re-radiating antenna.

36. An indoor reinforcement system as claimed in claim 35, wherein said satellite signals are characterized by a selected symbol period, and the duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is maintained to be less than a selected amount of said symbol duration by limiting the length of said at least one cable.

37. An indoor reinforcement system as claimed in claim 36, wherein said duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is no more than between 20 percent and 25 percent of said selected symbol period.

38. A reinforcement system for receiving a satellite signals transmitted in a digital broadcasting system using a radio receiver located outdoors, wherein said satellite signals are characterized by a selected symbol period, comprising at least two terrestrial repeaters, said terrestrial repeaters being characterized by a height h and being spaced apart by a distance d, the slant distance $(d^2 + h^2)^{1/2}$ from one of said terrestrial repeaters to said radio receiver being selected to limit a delay in reception of said satellite signals at said radio receiver from one of said terrestrial repeaters to between 20 percent and 25 percent of said symbol period.

39. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a first satellite configured to receive said broadcast program from said earth station and to transmit at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers; and

at least one terrestrial repeater configured to receive said first satellite signal and to generate and transmit at least one terrestrial signal from said first satellite signal comprising at least a portion of said broadcast program, wherein said satellite signal and said terrestrial signal are each modulated using a multipath-tolerant modulation technique.

40. A system as claimed in claim 39, wherein said first satellite signal is formatted in accordance with at least one of time division multiplexing and code division multiplexing.

41. A system as claimed in claim 39, wherein said terrestrial signal is formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

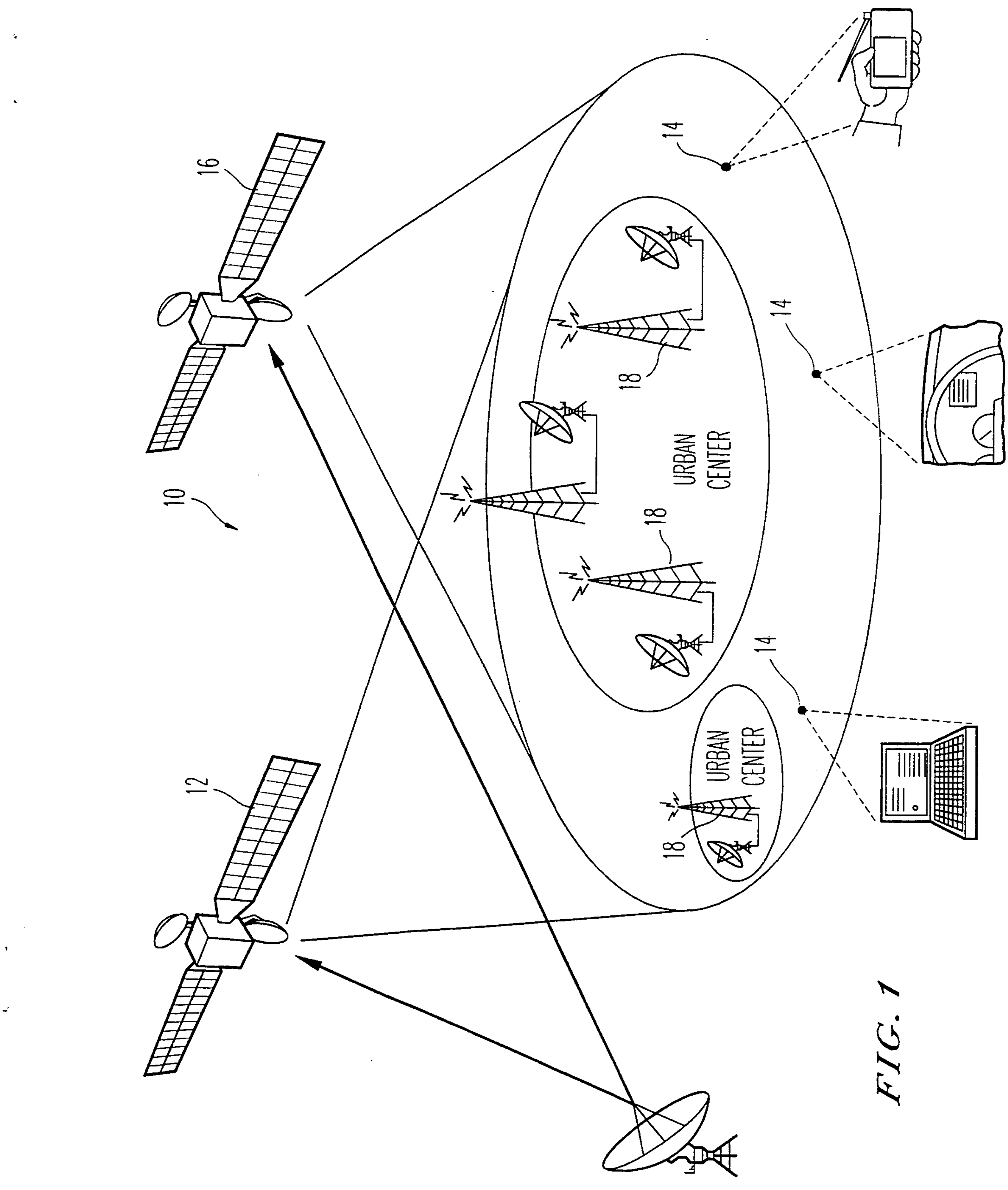
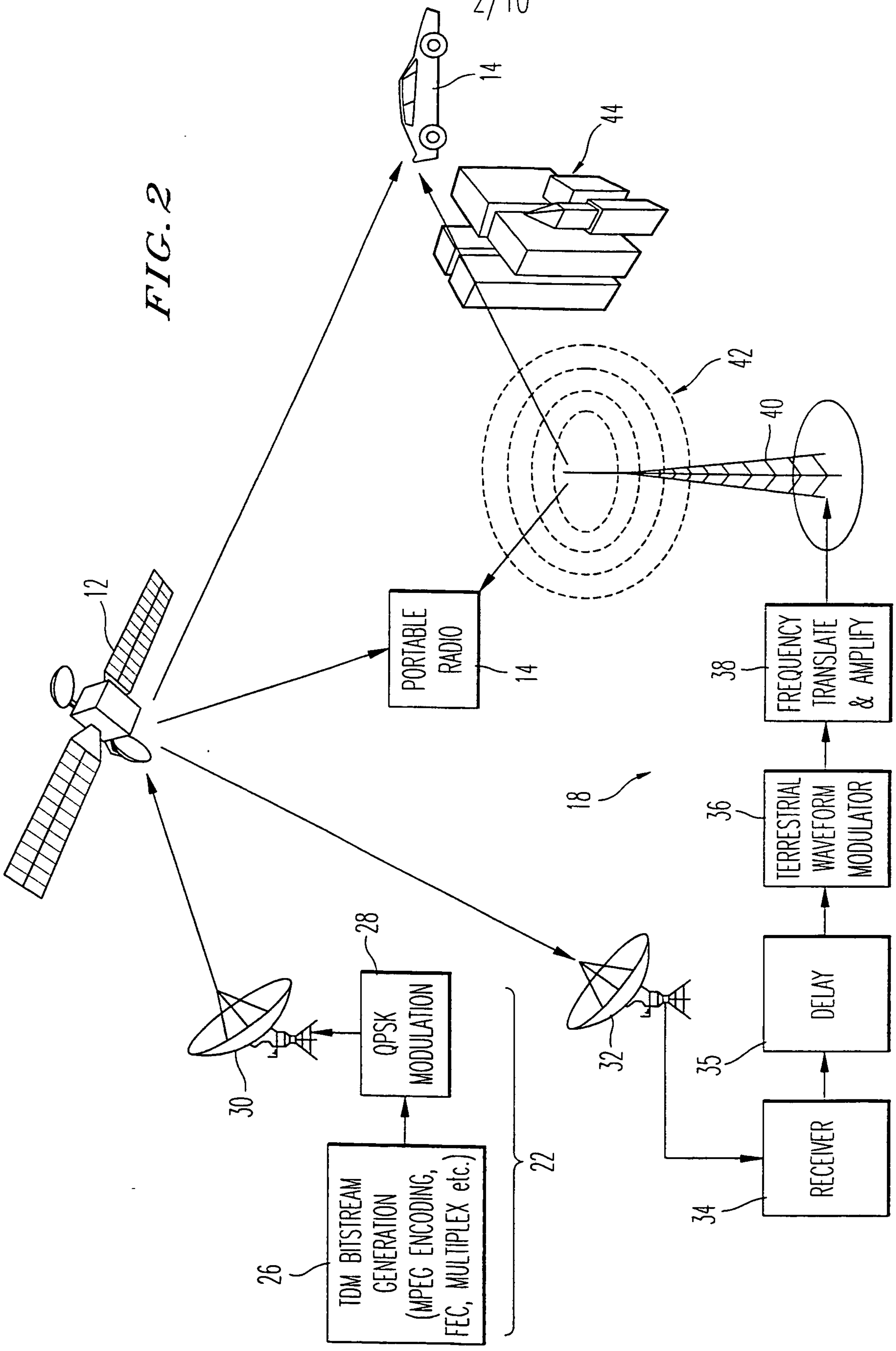


FIG. 1



TDM BITSTREAM GENERATION (MPEG ENCODING, FEC, MULTIPLEX etc.)
26
QPSK MODULATION
28
22
30
12
PORTABLE RADIO
14
14
44
42
40
32
RECEIVER
34
DELAY
35
TERRESTRIAL WAVEFORM MODULATOR
36
FREQUENCY TRANSLATE & AMPLIFY
38
18

FIG. 2

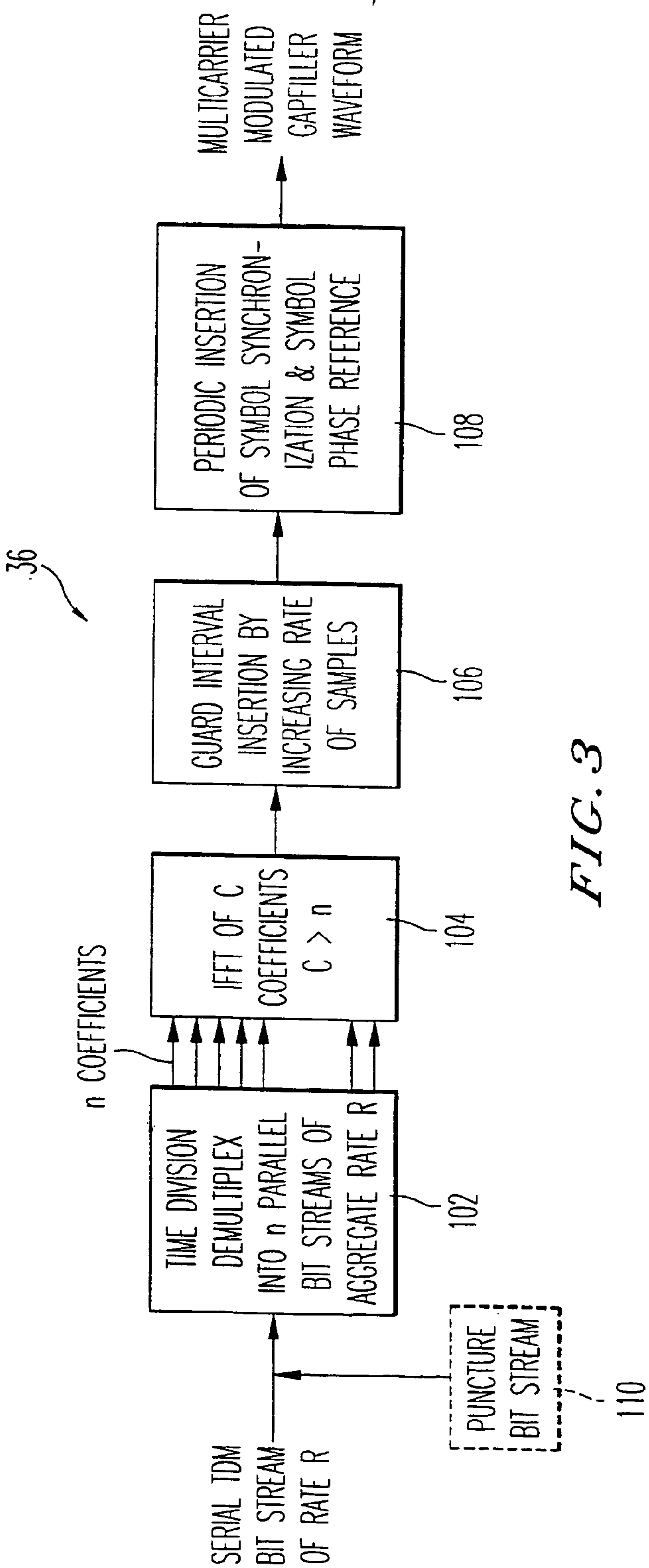

MULTICARRIER
MODULATED
GAPFILLER
WAVEFORM
PERIODIC INSERTION
OF SYMBOL SYNCHRON-
IZATION & SYMBOL
PHASE REFERENCE
108
36
GUARD INTERVAL
INSERTION BY
INCREASING RATE
OF SAMPLES
106
IFFT OF C
COEFFICIENTS
C > n
104
n COEFFICIENTS
TIME DIVISION
DEMULTIPLEX
INTO n PARALLEL
BIT STREAMS OF
AGGREGATE RATE R
102
PUNCTURE
BIT STREAM
110
SERIAL TDM
BIT STREAM
OF RATE R

FIG. 3

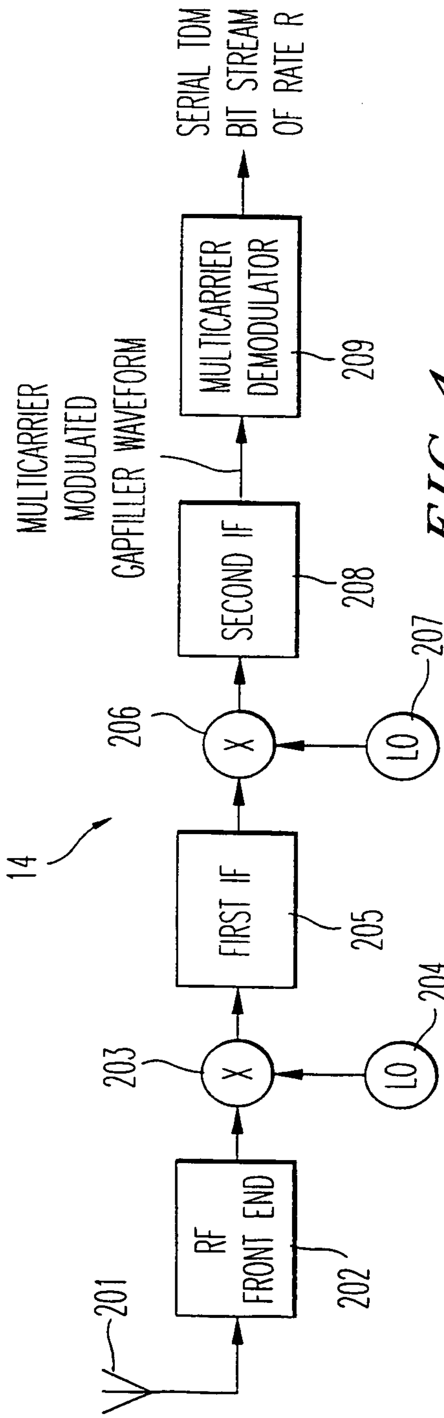

14
201
RF
FRONT END
202
203
X
LO
204
FIRST IF
205
206
X
LO
207
SECOND IF
208
MULTICARRIER
MODULATED
GAPFILLER WAVEFORM
MULTICARRIER
DEMODULATOR
209
SERIAL TDM
BIT STREAM
OF RATE R

FIG. 4

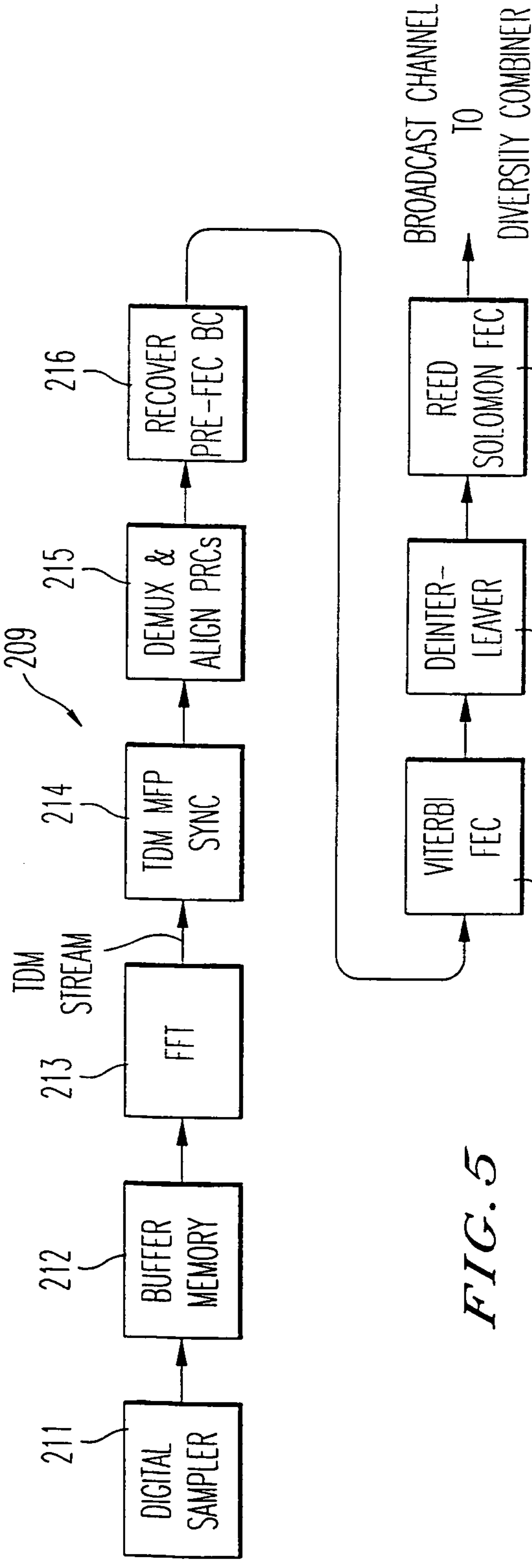

209
211
DIGITAL
SAMPLER
212
BUFFER
MEMORY
213
FFT
TDM
STREAM
214
TDM MFP
SYNC
215
DEMUX &
ALIGN PRCs
216
RECOVER
PRE-FEC BC
VITERBI
FEC
217
DEINTER-
LEAVER
218
REED
SOLOMON FEC
219
BROADCAST CHANNEL
TO
DIVERSITY COMBINER
240

FIG. 5

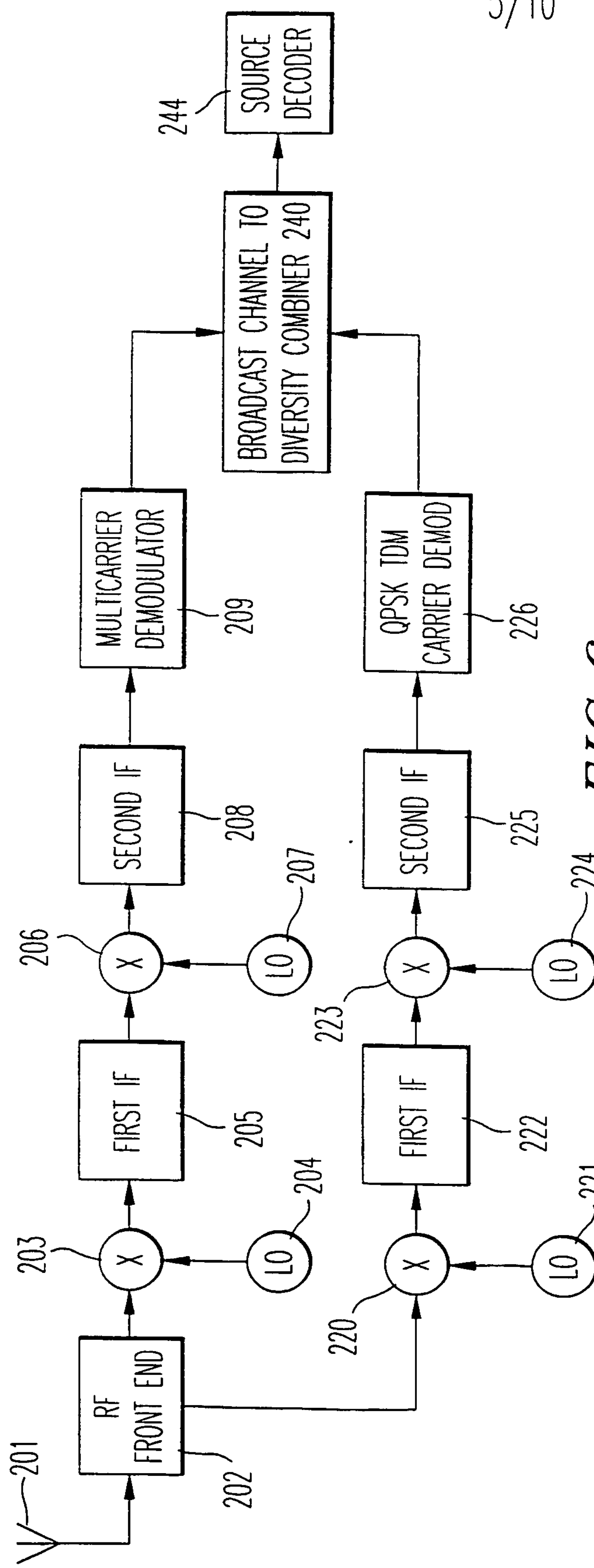

201
RF FRONT END
202
203
LO
204
FIRST IF
205
206
LO
207
SECOND IF
208
MULTICARRIER DEMODULATOR
209
220
LO
221
FIRST IF
222
223
LO
224
SECOND IF
225
QPSK TDM CARRIER DEMOD
226
BROADCAST CHANNEL TO DIVERSITY COMBINER 240
244
SOURCE DECODER

FIG. 6

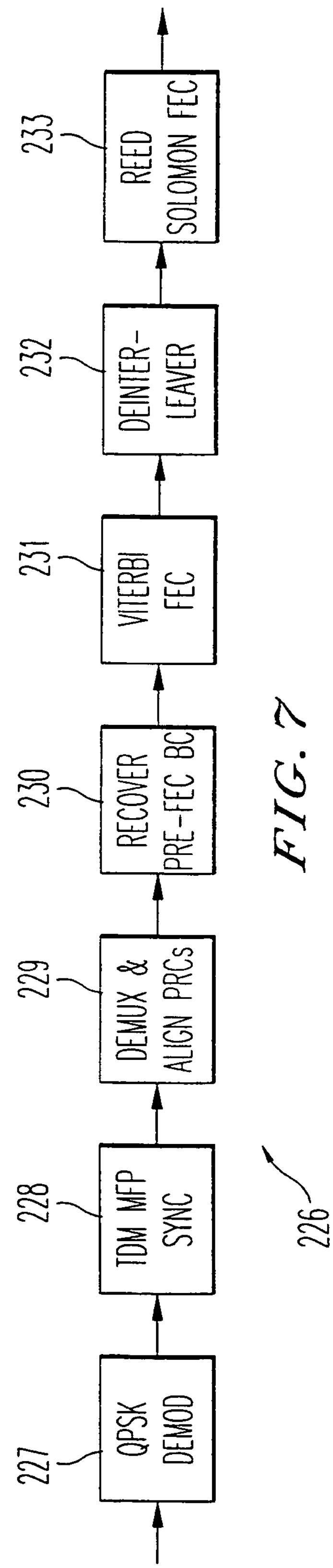
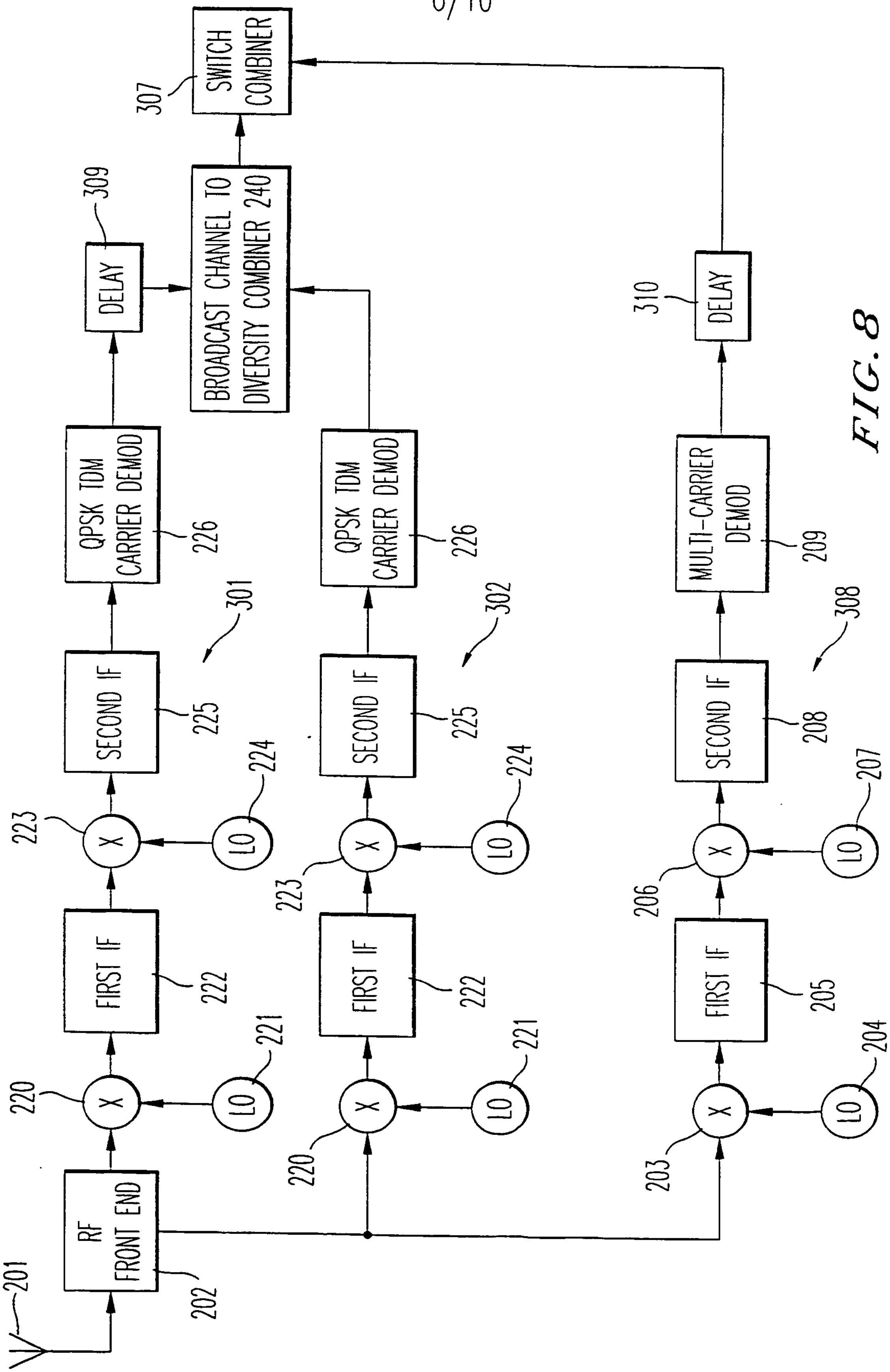

227
QPSK DEMOD
228
TDM MFP SYNC
229
DEMUX & ALIGN PRCs
230
RECOVER PRE-FEC BC
231
VITERBI FEC
232
DEINTER-LEAVER
233
REED SOLOMON FEC
226

FIG. 7



SWITCH COMBINER
307
BROADCAST CHANNEL TO DIVERSITY COMBINER 240
DELAY
309
DELAY
310
QPSK TDM CARRIER DEMOD
226
QPSK TDM CARRIER DEMOD
226
MULTI-CARRIER DEMOD
209
301
302
308
SECOND IF
225
SECOND IF
225
SECOND IF
208
223
X
LO
224
223
X
LO
224
206
X
LO
207
FIRST IF
222
FIRST IF
222
FIRST IF
205
220
X
LO
221
220
X
LO
221
203
X
LO
204
RF FRONT END
202
201

FIG. 8

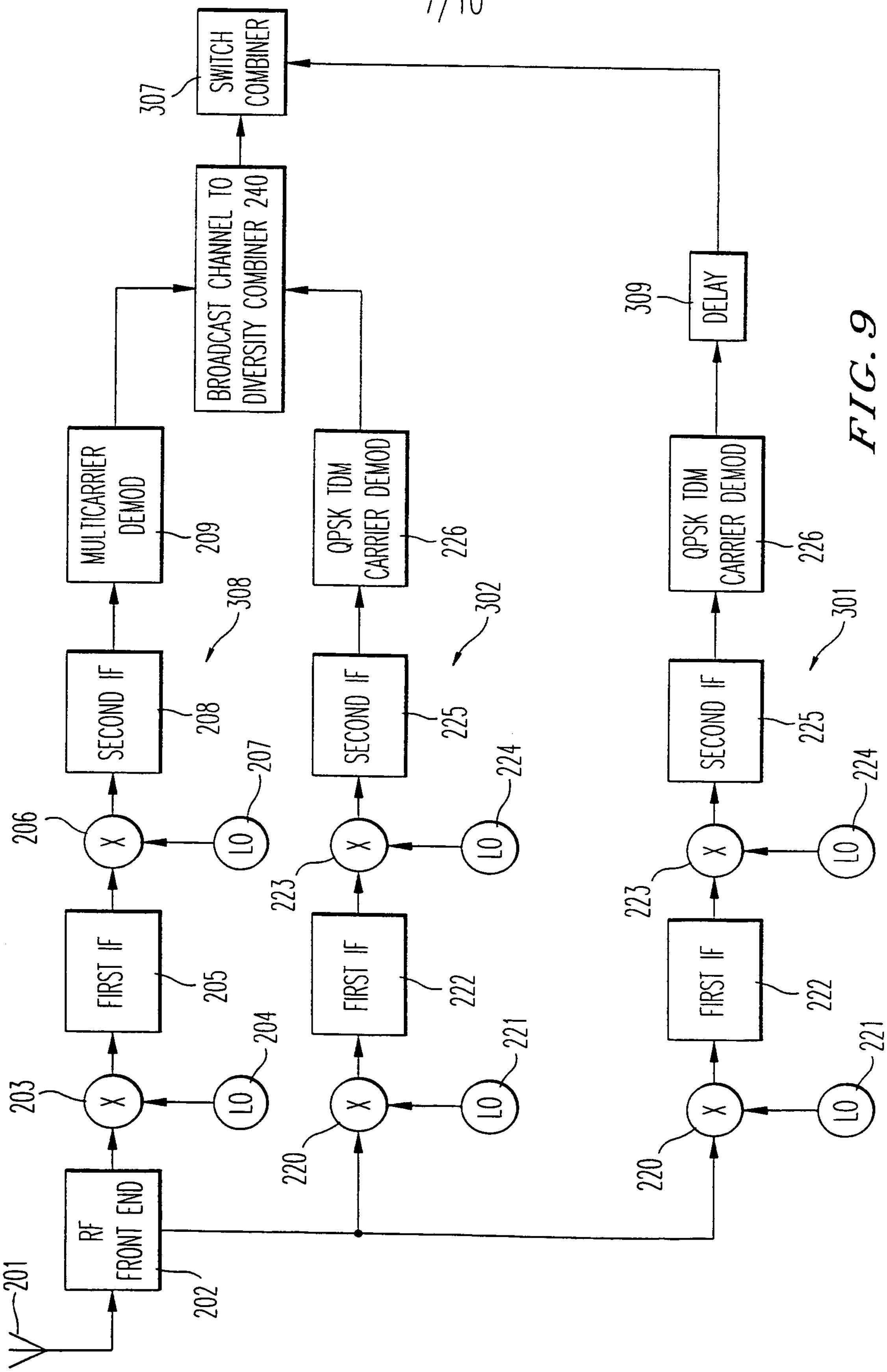

SWITCH COMBINER
307
BROADCAST CHANNEL TO DIVERSITY COMBINER 240
DELAY
309
MULTICARRIER DEMOD
209
QPSK TDM CARRIER DEMOD
226
308
302
301
SECOND IF
208
225
206
207
223
224
LO
X
FIRST IF
205
222
203
204
220
221
RF FRONT END
201
202

FIG. 9

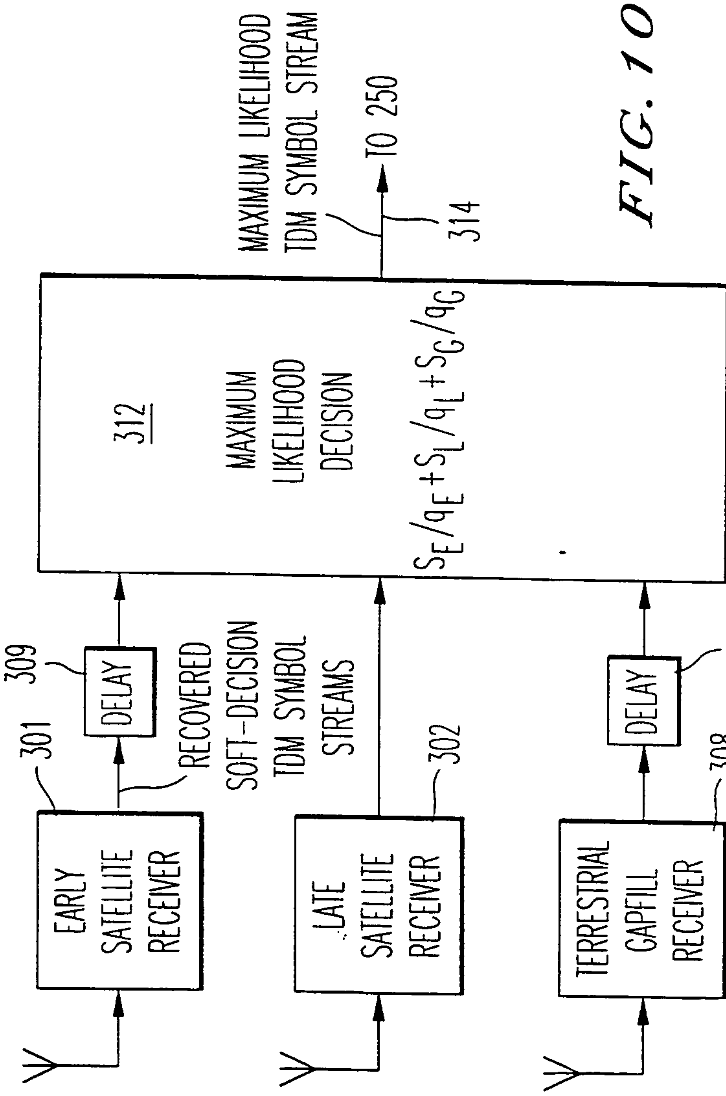

EARLY SATELLITE RECEIVER
301
LATE SATELLITE RECEIVER
302
TERRESTRIAL GAPFILL RECEIVER
308
DELAY
309
DELAY
310
RECOVERED SOFT-DECISION TDM SYMBOL STREAMS
312
MAXIMUM LIKELIHOOD DECISION
$S_E/q_E+S_L/q_L+S_G/q_G$
MAXIMUM LIKELIHOOD TDM SYMBOL STREAM
314
TO 250

FIG. 10

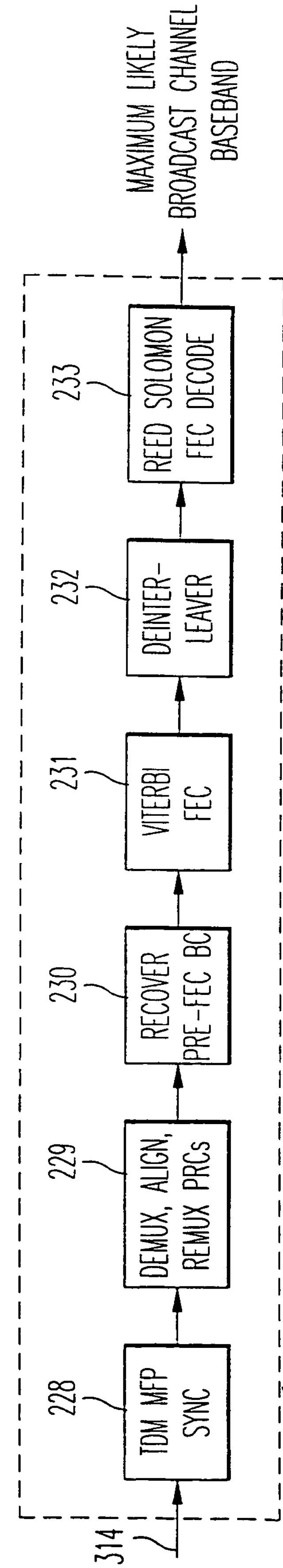

314
228
TDM MFP SYNC
229
DEMUX, ALIGN, REMUX PRCs
230
RECOVER PRE-FEC BC
231
VITERBI FEC
232
DEINTER-LEAVER
233
REED SOLOMON FEC DECODE
MAXIMUM LIKELY BROADCAST CHANNEL BASEBAND
250

FIG. 11

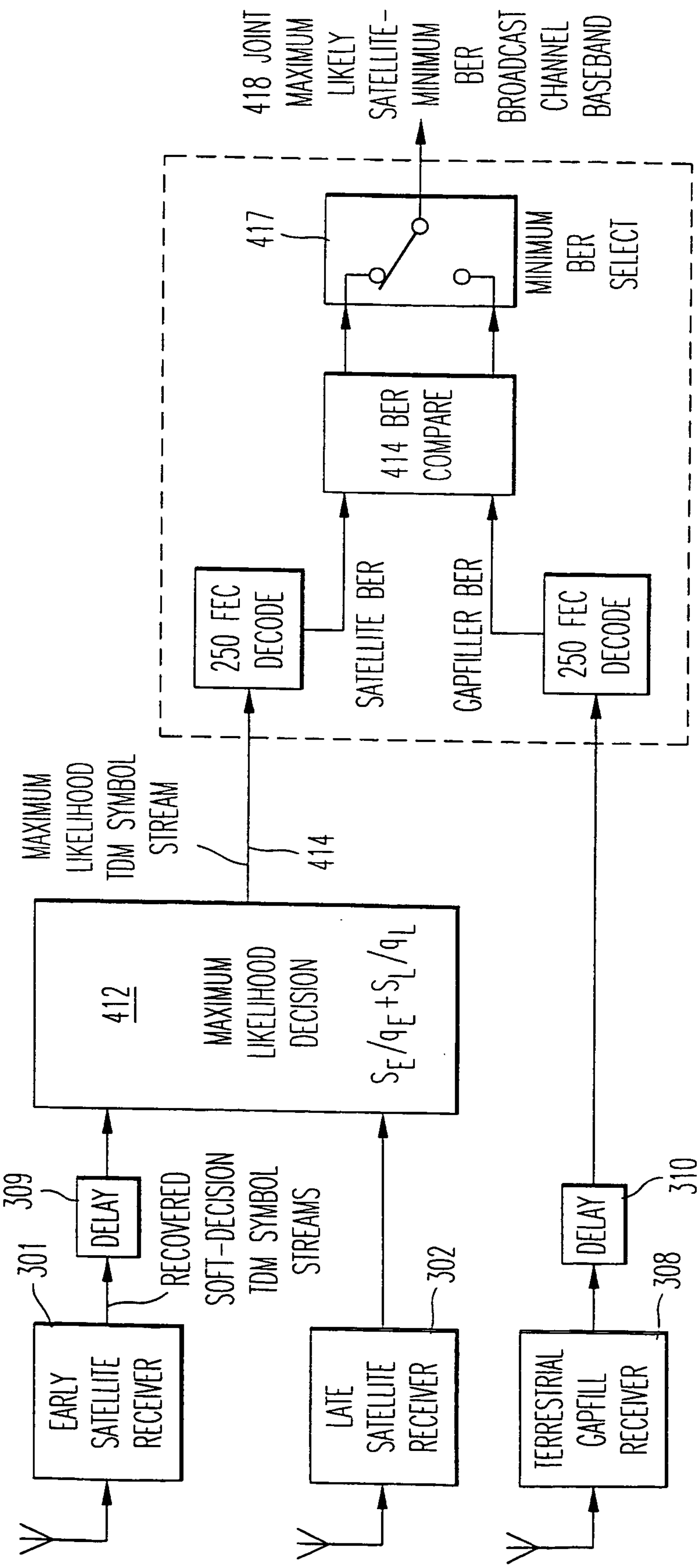

418 JOINT MAXIMUM LIKELY SATELLITE-MINIMUM BER BROADCAST CHANNEL BASEBAND
417
MINIMUM BER SELECT
414 BER COMPARE
SATELLITE BER
GAPFILLER BER
250 FEC DECODE
250 FEC DECODE
MAXIMUM LIKELIHOOD TDM SYMBOL STREAM
414
412
MAXIMUM LIKELIHOOD DECISION
$S_E/q_E+S_L/q_L$
309
DELAY
RECOVERED SOFT-DECISION TDM SYMBOL STREAMS
301
EARLY SATELLITE RECEIVER
302
LATE SATELLITE RECEIVER
310
DELAY
308
TERRESTRIAL GAPFILL RECEIVER

FIG. 12

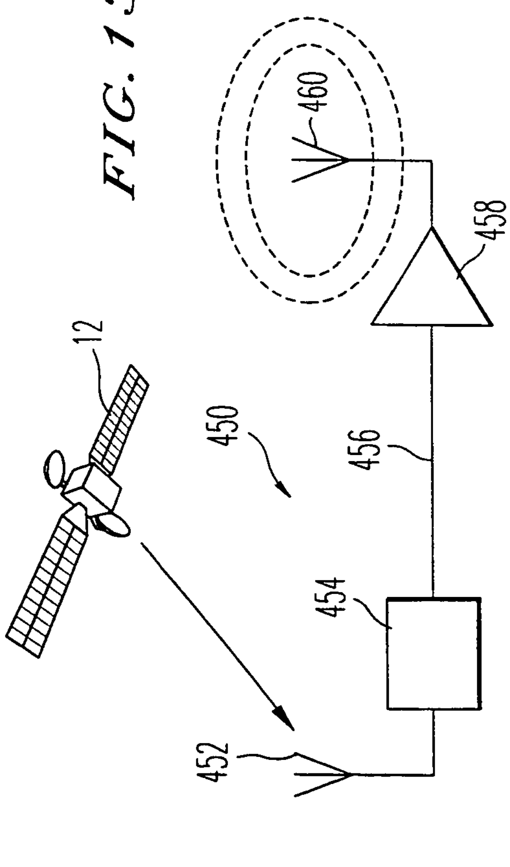

12
450
452
454
456
458
460

FIG. 13

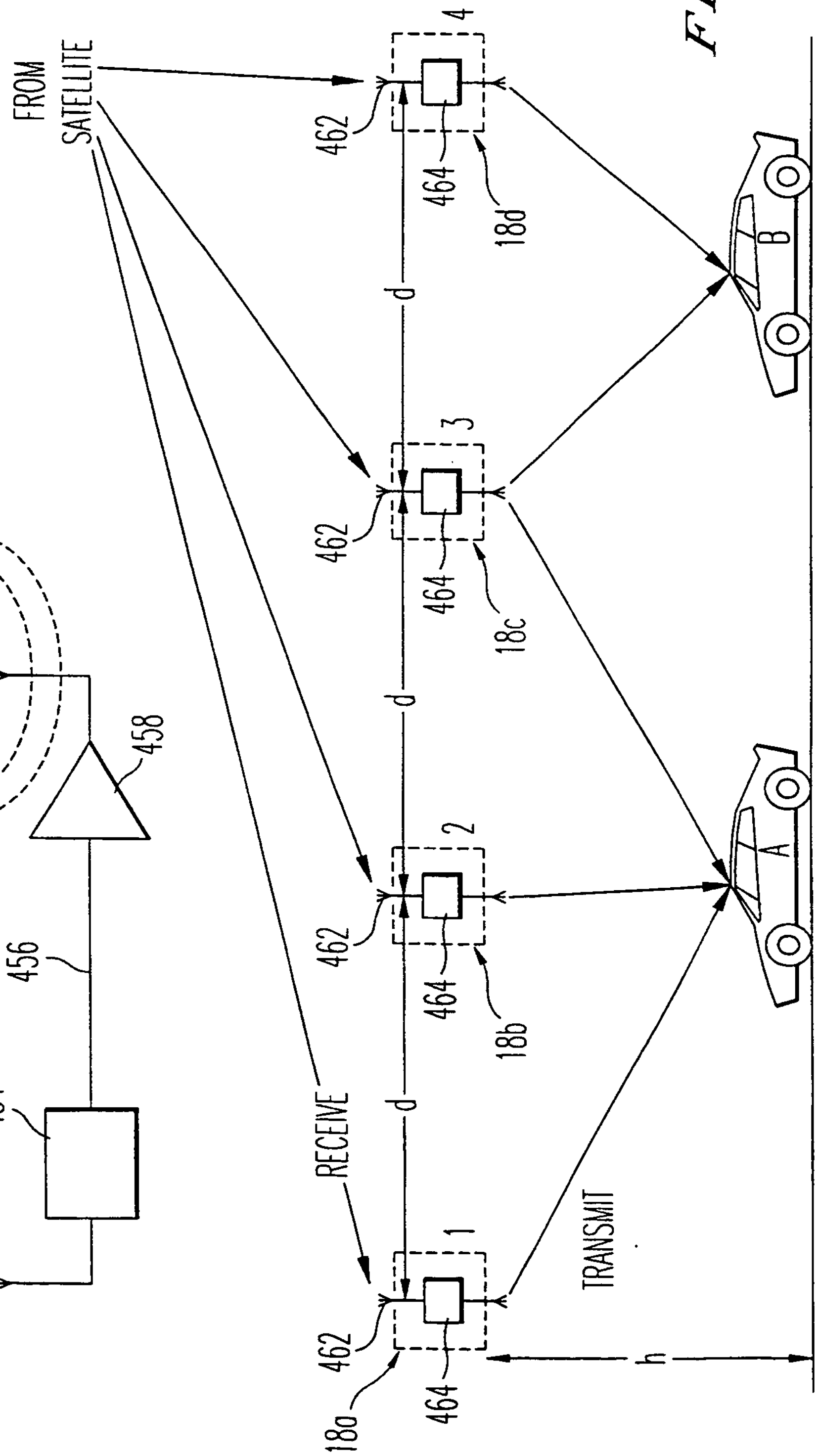

FROM SATELLITE
RECEIVE
TRANSMIT
1
2
3
4
462
464
18a
18b
18c
18d
d
h
A
B

FIG. 14

REPLACE BY ART 34

What is Claimed Is:

1. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and

at least one terrestrial repeater for receiving said satellite signal and generating and transmitting at least one terrestrial signal from said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

2. A system as claimed in claim 1, wherein said satellite is operable to modulate said broadcast program in accordance with at least one of time division multiplexing and code division multiplexing, and said terrestrial repeater is operable to modulate said terrestrial signal using at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptively equalized time division multiplexing, multicarrier modulation and code division multiplexing.

3. A system as claimed in claim 1, wherein said terrestrial repeater is operable to modulate said terrestrial signal using multicarrier modulation.

4. A system as claimed in claim 3, wherein said terrestrial repeater is operable to receive said satellite signal and to demodulate said satellite signal into a baseband signal prior to modulating said baseband signal using multicarrier modulation.

5. A system as claimed in claim 1, wherein said satellite signal is assigned a first code division multiple access channel code and said terrestrial signal is assigned a second code division multiple access channel code.

6. A system as claimed in claim 1, further comprising a second satellite, said second satellite being operable to receive said broadcast program from said earth station and to

transmit at least one second satellite signal comprising said at least a portion of said broadcast program to said radio receivers on said first carrier frequency and delayed a predetermined period of time with respect to the transmission of the other said satellite signal.

7. A terrestrial repeater for re-radiating broadcast signals to radio receivers comprising:

a receiver for receiving said broadcast signals; and

a terrestrial waveform modulator for generating terrestrial signals comprising said broadcast signals, said terrestrial signals being modulated by said terrestrial waveform modulator in accordance with multicarrier modulation.

8. A terrestrial repeater as claimed in claim 7, wherein said broadcast signals are transmitted to said radio receivers from a satellite using a first carrier frequency, said terrestrial waveform modulator being operable to transmit said terrestrial signals to said radio receivers using a second carrier frequency.

9. A terrestrial repeater as claimed in claim 7, wherein said terrestrial waveform modulator comprises:

a time division demultiplexer for demultiplexing said broadcast signals from a serial time division multiplexed bit stream into a plurality of parallel bit streams; and

an inverse fast Fourier transform device for generating a digital analog signal comprising a plurality of discrete Fourier transform coefficients.

10. A method of converting a time division multiplexed bit stream into a plurality of multicarrier modulated signals at a terrestrial repeater comprising the steps of:

receiving said time division multiplexed bit stream from a satellite;

dividing said time division multiplexed bit stream into a plurality of parallel bit paths;

representing each of a predetermined number of bits in each of said plurality of bit paths as a symbol comprising an imaginary component and a real component;

providing said symbols to parallel inputs of an inverse Fourier transform converter as complex number frequency coefficient inputs to generate outputs which are narrow band, orthogonal carriers; and

re-radiating said narrow band, orthogonal carriers.

11. A method as claimed in claim 10, further comprising the step of generating a guard interval for said carriers.

12. A method as claimed in claim 11, wherein said generating step comprises the steps of:

allocating a fraction of the symbol period corresponding to the duration of each of said symbols to guard time; and

reducing the duration of each of said symbols.

13. A method as claimed in claim 12, wherein said reducing step comprises the steps of:

storing said outputs of said inverse Fourier transform converter in a memory device every said symbol period; and

reading from said memory device after each said fraction of said symbol period has elapsed.

14. A method as claimed in claim 11, wherein said generating step further comprises the step of filling said guard interval with a subset of said outputs of said inverse Fourier transform.

15. A method as claimed in claim 10, further comprising the step of inserting a synchronization symbol every predetermined number of said symbol periods to synchronize a sampling window corresponding to said fraction of said symbol period with respect to said carriers every said symbol period at a receiver for said plurality of multicarrier modulated signals.

16. A method as claimed in claim 10, further comprising the step of puncturing said time division multiplexed bit stream to reduce the total bandwidth associated with said carriers.

17. A method as claimed in claim 16, wherein said puncturing step comprises the step of selectively eliminating bits from said time division multiplexed bit stream prior to providing said symbols to parallel inputs of an inverse Fourier transform converter.

18. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a first satellite configured to receive said broadcast program from said earth station and to transmit at least one first satellite signal comprising at least a portion of said broadcast program to said radio receivers, said first satellite signal being formatted in accordance with at least one of time division multiplexing and code division multiplexing; and

at least one terrestrial repeater configured to receive said first satellite signal and to generate and transmit at least one terrestrial signal from said first satellite signal comprising at least a portion of said broadcast program, said terrestrial signal being formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

19. A digital broadcasting system as claimed in claim 18, wherein said first satellite signal is transmitted to said radio receivers using a first carrier frequency, and said at last one terrestrial signal is transmitted to said radio receivers using a second carrier frequency.

20. A digital broadcasting system as claimed in claim 18, wherein at least one of said radio receivers is configured to receive said first satellite signal and said terrestrial signal and comprises a diversity combiner to generate an output signal from said first satellite signal and said terrestrial signal.

21. A digital broadcasting system as claimed in claim 18, further comprising a second satellite configured to receive said broadcast program from said earth station and to transmit at least one second satellite signal comprising at least a portion of said broadcast program to said radio receivers, said second satellite signal being delayed with respect to said first satellite signal by a selected time delay, said second satellite signal being formatted in accordance with the corresponding at least one of time division multiplexing and code division multiplexing employed by said first satellite.

22. A digital broadcasting system as claimed in claim 21, wherein at least one of said radio receivers is configured to receive said first satellite signal, said second satellite signal and said terrestrial signal, to delay at least one of said first satellite signal and said terrestrial signal in accordance with said selected time delay, and to generate an output signal from first satellite signal, said second satellite signal and said terrestrial signal.

23. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner and a switched combiner, said radio receiver using said diversity combiner to perform maximum likelihood decision combining of said first satellite signal and said second satellite signals and said switch combiner to select between the output of said diversity combiner and said terrestrial signal depending on which of said output of said diversity combiner and said terrestrial signal comprises the least number of bit errors.

24. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner to perform maximum likelihood decision combining of said first satellite signal, said second satellite signals and said terrestrial signal.

25. A receiver for receiving a broadcast signal in a digital broadcasting system comprising:

a first receiver arm for receiving a first satellite signal transmitted from a first satellite on a first carrier frequency, said first satellite signal comprising at least a portion of said broadcast signal and being formatted in accordance with at least one of time

division multiplexing and code division multiplexing, said first receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal;

a second receiver arm for receiving a terrestrial signal transmitted on a second carrier frequency, said terrestrial signal comprising said at least a portion of said broadcast signal and being formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation, said second receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal; and

a combiner for generating an output signal from said first satellite signal and said terrestrial signal.

26. A receiver as claimed in claim 25, further comprising:

a third receiver arm for receiving a second satellite signal from a second satellite and delayed with respect to said first satellite signal in accordance with a selected time delay, said second satellite signal comprising at least a portion of said broadcast signal and being formatted in accordance with the corresponding at least one of time division multiplexing and code division multiplexing employed by said first satellite, said first receiver arm comprising a demodulator for recovering said at least a portion of said broadcast signal; and

a delay device for delaying said first satellite signal in accordance with said selected time delay, said combiner being operable to generate an output signal from said first satellite signal, said second satellite signal and said terrestrial signal.

27. A method of transmitting a broadcast program to radio receivers comprising the steps of:

formatting a broadcast signal for transmission to said radio receivers as a first signal in accordance with one of time division multiplexing and code division multiplexing;

transmitting said first signal to said radio receivers from a first satellite on a first carrier frequency;

formatting said broadcast signal for transmission to said radio receivers as a second signal in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation; and

transmitting said second signal to said radio receivers from a terrestrial repeater on a second carrier frequency.

28. A method as claimed in claim 27, wherein said formatting step for formatting said broadcast signal as said second signal comprises the steps of:

receiving said first signal at said terrestrial repeater; and

performing baseband processing of said first signal prior to formatting in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

29. A method as claimed in claim 28, further comprising the step of receiving said first signal and said second signal at one of said radio receivers.

30. A method as claimed in claim 29, further comprising the step of demodulating each of said first signal and said second signal to remove said respective formatting and to recover a first recovered broadcast signal and a second recovered broadcast signal, respectively.

31. A method as claimed in claim 30, further comprising the steps of generating an output broadcast signal from said first recovered broadcast signal and said second recovered broadcast signal.

32. A method as claimed in claim 31, wherein said generating step comprises the step of performing maximum likelihood combining of said first recovered broadcast signal and said second recovered broadcast signal.

33. A method as claimed in claim 27, further comprising the steps of:

formatting a broadcast signal for transmission to said radio receivers as a third signal in accordance with at least one of time division multiplexing and code division multiplexing;

transmitting said third signal to said radio receivers from a second satellite, said transmission being delayed with respect to said first signal by a predetermined period of time.

34. A method as claimed in claim 33, further comprising the steps of:

receiving said first signal, said second signal and said third signal at one of said radio receivers;

demodulating each of said first signal, said second signal and said third signal to remove said respective formatting and to recover a first recovered broadcast signal, a second recovered broadcast signal and a third recovered broadcast signal, respectively; and

generating an output broadcast signal from said first recovered broadcast signal, said second recovered broadcast signal and said third recovered broadcast signal.

35. An indoor reinforcement system for receiving a satellite signals transmitted in a digital broadcasting system using a radio receiver located indoors, comprising:

a line of sight antenna for receiving line of sight satellite signals;

a radio frequency front-end unit connected to said line of sight antenna for passing frequency spectrum comprising said satellite signal with low noise;

at least one indoor amplifier;

at least one cable for connecting said radio frequency front-end unit to said indoor amplifier; and

at least one indoor re-radiating antenna connected to said indoor amplifier, said indoor re-radiating antenna having a power level selected to be sufficiently high to achieve satisfactory indoor reception of said satellite signals at radio receivers at indoor locations where line of sight reception of said satellite signals is not possible and sufficiently low to prevent interference by said satellite signals transmitted between said line of sight antenna and said indoor re-radiating antenna.

36. An indoor reinforcement system as claimed in claim 35, wherein said satellite signals are characterized by a selected symbol period, and the duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is maintained to be less than a selected amount of said symbol duration by limiting the length of said at least one cable.

37. An indoor reinforcement system as claimed in claim 36, wherein said duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is no more than between 20 percent and 25 percent of said selected symbol period.

38. A reinforcement system for receiving a satellite signals transmitted in a digital broadcasting system using a radio receiver located outdoors, wherein said satellite signals are characterized by a selected symbol period, comprising at least two terrestrial repeaters, said terrestrial repeaters being characterized by a height *h* and being spaced apart by a distance *d*, the slant distance $(d^2 + h^2)^{1/2}$ from one of said terrestrial repeaters to said radio receiver being selected to limit a delay in reception of said satellite signals at said radio receiver from one of said terrestrial repeaters to between 20 percent and 25 percent of said symbol period.

39. A digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising:

a first satellite configured to receive said broadcast program from said earth station and to transmit at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers; and

at least one terrestrial repeater configured to receive said first satellite signal and to generate and transmit at least one terrestrial signal from said first satellite signal comprising at least a portion of said broadcast program, wherein said satellite signal and said terrestrial signal are each modulated using a multipath-tolerant modulation technique.

40. A system as claimed in claim 39, wherein said first satellite signal is formatted in accordance with at least one of time division multiplexing and code division multiplexing.

41. A system as claimed in claim 39, wherein said terrestrial signal is formatted in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing and multicarrier modulation.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 36010	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/US98/14280	International filing date *(day/month/year)* 10 JULY 1998	(Earliest) Priority Date *(day/month/year)* 27 MARCH 1998
Applicant WORLDSPACE MANAGEMENT CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (See Box I).

2. [ ] **Unity of invention is lacking** (See Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] transcribed by this Authority.

4. With regard to the **title**,
   - [X] the text is approved as submitted by the applicant.
   - [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   - [ ] the text is approved as submitted by the applicant.
   - [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. **The figure of the drawings to be published with the abstract is:**

   Figure No. 2
   - [X] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The technical features mentioned in the abstract do not include a reference sign between parentheses (PCT Rule 8.1(d)).

A digital broadcast system (Fig. 2) is provided which uses a satellite direct radio broadcast system having different downlink modulation options in combination with a terresterial repeater network employing different re-broadcasting modulation options to achieve high availabilty reception by mobile radios (14), static radios, and portable radios (14) in urban areas, suburban metropolitan areas, and rural areas, including geographically open areas and geographic areas characterized by high terrain elevations. Two-arm and three-arm receivers are provided which each comprise a combined architecture for receiving both satellite and terresterial signals, and for maximum likelihood combining of received signals for diversity purposes. A terresterial repeater is provided for reformatting a TDM satellite signal as a multicarrier modulated terresterial signal. Configuratios for indoor and outdoor terresterial repeaters are also provided.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/14280

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04H 1/00; H04B 7/155
US CL :370/315; 375/347; 455/17, 500, 504
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/315; 375/347, 211, 349; 455/17, 500, 504, 427

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,485,485 A (BRISKMAN et al.) 16, January 1996, see entire documant.	1-41
A	US 5,303,393 A (NOREEN et al.) 12 april 1994, see entire document.	1-41
A	US 5,319,673 A (BRISKMAN) 07 June 1994, see entire document.	1-41
A	US 5,659,353 A (KOSTRESKI et al.) 19 August 1997, see entire document.	1-41

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
30 JANUARY 1999

Date of mailing of the international search report
27 APR 1999

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
MIN JUNG Eugenia Logan
Telephone No. (703) 305-4363

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: JOHN E. HOLMES
ROYLANCE, ABRAMS, BERDO & GOODMAN, LLP
1225 CONNECTICUT AVE., NW
WASHINGTON, DC 20036

Doc'd ______ File 36010
Rec'd
APR 28 1999
ROYLANCE, ABRAMS
BERDO & GOODMAN, L.L.P.
BY ______

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of Mailing (day/month/year) 27 APR 1999
Applicant's or agent's file reference 36010	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US98/14280	International filing date (day/month/year) 10 JULY 1998
Applicant WORLDSPACE MANAGEMENT CORPORATION	

1. [X] The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MIN JUNG Telephone No. (703) 305-4363

Form PCT/ISA/220 (January 1994)★

(See notes on accompanying sheet)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: JOHN E. HOLMES
ROYLANCE, ABRAMS, BERDO & GOODMAN, LLP
1225 CONNECTICUT AVE., NW
WASHINGTON, DC 20036

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of Mailing *(day/month/year)* 27 APR 1999
Applicant's or agent's file reference 36010	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US98/14280	International filing date *(day/month/year)* 10 JULY 1998
Applicant WORLDSPACE MANAGEMENT CORPORATION	

1. [X] The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompanying sheet.

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34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:**

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MIN JUNG Telephone No. (703) 305-4363

Form PCT/ISA/220 (January 1994)★

(See notes on accompanying sheet)

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 30 November 1999 (30.11.99)	
International application No. PCT/US98/14280	**Applicant's or agent's file reference** 36010
International filing date (day/month/year) 10 July 1998 (10.07.98)	**Priority date** (day/month/year) 27 March 1998 (27.03.98)
Applicant CAMPANELLA, S., Joseph	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

26 October 1999 (26.10.99)

☐ in a notice effecting later election filed with the International Bureau on:

____

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Kiwa Mpay Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

RECD 08 MAY 2000

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

16

Applicant's or agent's file reference 36010	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US98/14280	International filing date *(day/month/year)* 10 JULY 1998	Priority date *(day/month/year)* 27 MARCH 1998
International Patent Classification (IPC) or national classification and IPC IPC(7): H04H 1/00; H04B 7/155 and US Cl.: 370/315; 375/347; 455/17, 500, 504		
Applicant WORLDSPACE MANAGEMENT CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 26 OCTOBER 1999	Date of completion of this report 18 APRIL 2000
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MIN JUNG For Benjamin Zaffer Telephone No. (703) 305-4363

Form PCT/IPEA/409 (cover sheet) (July 1998) ★

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

I. Basis of the report

1. With regard to the **elements** of the international application:*

[X] the international application as originally filed

[X] the description:

pages 1-25, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of

[X] the claims:

pages 26-35, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of

[X] the drawings:

pages 1-10, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of

[X] the sequence listing part of the description:

pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ______ which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained in the international application in printed form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. [X] The amendments have resulted in the cancellation of:

[X] the description, pages none

[X] the claims, Nos. none

[X] the drawings, sheets/~~fig~~ none

5. [ ] This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	1-41	YES
	Claims	none	NO
Inventive Step (IS)	Claims	1-41	YES
	Claims	none	NO
Industrial Applicability (IA)	Claims	1-41	YES
	Claims	none	NO

2. citations and explanations (Rule 70.7)

Claims 1-41 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and at least one terrestrial repeater for receiving said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

-------------------- NEW CITATIONS --------------------

US 5,726,980 A (RICKARD) 10 March 1998, see Abstract.

US 5,636,246 A (TZANNES) 03 June 1997, see entire document.

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US, A, 5,864,579	26 JANUARY 1999	25 JULY 1996	NONE
US, A, 5,953,311	14 SEPTEMBER 1999	18 FEBRUARY 1997	NONE

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

PATENT COOPERATION TREATY

REC'D 17 AUG 2000

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 36010	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US98/14280	International filing date *(day/month/year)* 10 JULY 1998	Priority date *(day/month/year)* 27 MARCH 1998
International Patent Classification (IPC) or national classification and IPC IPC(7): H04H 1/00; H04B 7/155 and US Cl.: 370/315; 375/347; 455/17, 500, 504		
Applicant WORLDSPACE MANAGEMENT CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets.

[✓] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

- I [X] Basis of the report
- II [ ] Priority
- III [ ] Non-establishment of report with regard to novelty, inventive step or industrial applicability
- IV [ ] Lack of unity of invention
- V [X] Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI [X] Certain documents cited
- VII [ ] Certain defects in the international application
- VIII [ ] Certain observations on the international application

CORRECTED VERSION

Date of submission of the demand 26 OCTOBER 1999	Date of completion of this report 18 APRIL 2000
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MIN JUNG *Rugenia Logan* Telephone No. (703) 305-4363

Form PCT/IPEA/409 (cover sheet) (July 1998) ★

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed

☒ the description:
pages (See Attached), as originally filed
pages ______, filed with the demand
pages ______, filed with the letter of ______

☒ the claims:
pages (See Attached), as originally filed
pages ______, as amended (together with any statement) under Article 19
pages ______, filed with the demand
pages ______, filed with the letter of ______

☒ the drawings:
pages (See Attached), as originally filed
pages ______, filed with the demand
pages ______, filed with the letter of ______

☒ the sequence listing part of the description:
pages (See Attached), as originally filed
pages ______, filed with the demand
pages ______, filed with the letter of ______

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ______ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

☒ the description, pages none
☒ the claims, Nos. NONE
☒ the drawings, sheets/~~fig~~ none

5. ☒ This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	1-41	YES
	Claims	none	NO
Inventive Step (IS)	Claims	1-41	YES
	Claims	none	NO
Industrial Applicability (IA)	Claims	1-41	YES
	Claims	none	NO

2. citations and explanations (Rule 70.7)

Claims 1-41 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and at least one terrestrial repeater for receiving said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

-------------------- NEW CITATIONS --------------------
US 5,726,980 A (RICKARD) 10 March 1998, see Abstract.

US 5,636,246 A (TZANNES) 03 June 1997, see entire document.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US, A, 5,864,579	26 JANUARY 1999	25 JULY 1996	NONE
US, A, 5,953,311	14 SEPTEMBER 1999	18 FEBRUARY 1997	NONE

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

Sheet 10

I. BASIS OF REPORT:

This report has been drawn on the basis of the description,
page(s) 1-25, as originally filed.
page(s) NONE, filed with the demand.
and additional amendments:
NONE

This report has been drawn on the basis of the claims,
page(s) none, as originally filed.
page(s) NONE, as amended under Article 19.
page(s) NONE, filed with the demand.
and additional amendments:
Pages 26-34, filed with the letter dated March 24, 2000.

This report has been drawn on the basis of the drawings,
page(s) 1-10, as originally filed.
page(s) NONE, filed with the demand.
and additional amendments:
NONE

This report has been drawn on the basis of the sequence listing part of the description:
page(s) NONE, as originally filed.
pages(s) NONE, filed with the demand.
and additional amendments:
NONE

5. (Some) amendments are considered to go beyond the disclosure as filed:
NONE

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: JOHN E. HOLMES
ROYLANCE, ABRAMS, BERDO & GOODMAN, LLP
1225 CONNECTICUT AVE., NW
SUITE 315
WASHINGTON, DC 20036

36010

Doc'd ______ File ______
Rec'd
MAY 5 2000
ROYLANCE, ABRAMS
BERDO & GOODMAN, L.L.P.
BY ______

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing (day/month/year) 04 MAY 2000

Applicant's or agent's file reference	IMPORTANT NOTIFICATION
36010	

International application No.	International filing date (day/month/year)	Priority Date (day/month/year)
PCT/US98/14280	10 JULY 1998	27 MARCH 1998

Applicant
WORLDSPACE MANAGEMENT CORPORATION

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	MIN JUNG
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4363

Form PCT/IPEA/416 (July 1992)★

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: JOHN E. HOLMES
ROYLANCE, ABRAMS, BERDO & GOODMAN, LLP
1225 CONNECTICUT AVE., NW
SUITE 315
WASHINGTON, DC 20036

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing *(day/month/year)*	04 MAY 2000	
Applicant's or agent's file reference: 36010	IMPORTANT NOTIFICATION	
International application No.: PCT/US98/14280	International filing date *(day/month/year)*: 10 JULY 1998	Priority Date *(day/month/year)*: 27 MARCH 1998
Applicant: WORLDSPACE MANAGEMENT CORPORATION		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

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Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer MIN JUNG
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4363

Form PCT/IPEA/416 (July 1992)★

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 36010	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/US98/14280	International filing date *(day/month/year)* 10 JULY 1998	Priority date *(day/month/year)* 27 MARCH 1998
International Patent Classification (IPC) or national classification and IPC IPC(7): H04H 1/00; H04B 7/155 and US Cl.: 370/315; 375/347; 455/17, 500, 504		
Applicant WORLDSPACE MANAGEMENT CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 0 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☒ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 26 OCTOBER 1999	Date of completion of this report 18 APRIL 2000
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MIN JUNG Telephone No. (703) 305-4363

Form PCT/IPEA/409 (cover sheet) (July 1998) ★

I. Basis of the report

1. With regard to the **elements** of the international application:*

[X] the international application as originally filed

[X] the description:
pages 1-25, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______

[X] the claims:
pages 26-35, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of ______

[X] the drawings:
pages 1-10, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______

[X] the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ______

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ______ which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained in the international application in printed form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. [X] The amendments have resulted in the cancellation of:

[X] the description, pages none
[X] the claims, Nos. none
[X] the drawings, sheets/~~fig~~ none

5. [ ] This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	1-41	YES
	Claims	none	NO
Inventive Step (IS)	Claims	1-41	YES
	Claims	none	NO
Industrial Applicability (IA)	Claims	1-41	YES
	Claims	none	NO

2. citations and explanations (Rule 70.7)

Claims 1-41 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and at least one terrestrial repeater for receiving said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

-------------------- NEW CITATIONS --------------------

US 5,726,980 A (RICKARD) 10 March 1998, see Abstract.

US 5,636,246 A (TZANNES) 03 June 1997, see entire document.

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US, A, 5,864,579	26 JANUARY 1999	25 JULY 1996	NONE
US, A, 5,953,311	14 SEPTEMBER 1999	18 FEBRUARY 1997	NONE

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: JOHN E. HOLMES
ROYLANCE, ABRAMS, BERDO & GOODMAN, LLP
1225 CONNECTICUT AVE., NW
SUITE 315
WASHINGTON, DC 20036

Doc'd KXD File 36010
Rec'd
AUG 14 2000
ROYLANCE, ABRAMS
BERDO & GOODMAN, L.L.P.
BY

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing (day/month/year): 10 AUG 2000

Applicant's or agent's file reference	IMPORTANT NOTIFICATION
36010	

International application No.	International filing date (day/month/year)	Priority Date (day/month/year)
PCT/US98/14280	10 JULY 1998	27 MARCH 1998

Applicant
WORLDSPACE MANAGEMENT CORPORATION

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
MIN JUNG Eugenia Logan
Telephone No. (703) 305-4363

Form PCT/IPEA/416 (July 1992)★

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Applicant WORLDSPACE MANAGEMENT CORPORATION		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets.

   ☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
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Form PCT/IPEA/409 (cover sheet) (July 1998) ★

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/US98/14280

I. Basis of the report

1. With regard to the elements of the international application:*

☐ the international application as originally filed

☒ the description:

pages (See Attached), as originally filed

pages ____, filed with the demand

pages ____, filed with the letter of ____

☒ the claims:

pages (See Attached), as originally filed

pages ____, as amended (together with any statement) under Article 19

pages ____, filed with the demand

pages ____, filed with the letter of ____

☒ the drawings:

pages (See Attached), as originally filed

pages ____, filed with the demand

pages ____, filed with the letter of ____

☒ the sequence listing part of the description:

pages (See Attached), as originally filed

pages ____, filed with the demand

pages ____, filed with the letter of ____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ____ which is:

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☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

☒ the description, pages none

☒ the claims, Nos. NONE

☒ the drawings, sheets/~~fig~~ none

5. ☒ This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	1-41	YES
	Claims	none	NO
Inventive Step (IS)	Claims	1-41	YES
	Claims	none	NO
Industrial Applicability (IA)	Claims	1-41	YES
	Claims	none	NO

2. citations and explanations (Rule 70.7)

Claims 1-41 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a digital broadcasting system for transmitting a broadcast program to radio receivers, the broadcast program being generated at an earth station, comprising a satellite for receiving said broadcast program from said earth station and transmitting at least one satellite signal comprising at least a portion of said broadcast program to said radio receivers on a first carrier frequency; and at least one terrestrial repeater for receiving said satellite signal comprising said at least a portion of said broadcast program on a second carrier frequency and modulated in accordance with a multipath-tolerant modulation technique.

------------------- NEW CITATIONS -------------------

US 5,726,980 A (RICKARD) 10 March 1998, see Abstract.

US 5,636,246 A (TZANNES) 03 June 1997, see entire document.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US98/14280

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No. Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US, A, 5,864,579	26 JANUARY 1999	25 JULY 1996	NONE
US, A, 5,953,311	14 SEPTEMBER 1999	18 FEBRUARY 1997	NONE

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

I. BASIS OF REPORT:

This report has been drawn on the basis of the description,
page(s) 1-25, as originally filed.
page(s) NONE, filed with the demand.
and additional amendments:
NONE

This report has been drawn on the basis of the claims,
page(s) none, as originally filed.
page(s) NONE, as amended under Article 19.
page(s) NONE, filed with the demand.
and additional amendments:
Pages 26-34, filed with the letter dated March 24, 2000.

This report has been drawn on the basis of the drawings,
page(s) 1-10, as originally filed.
page(s) NONE, filed with the demand.
and additional amendments:
NONE

This report has been drawn on the basis of the sequence listing part of the description:
page(s) NONE, as originally filed.
pages(s) NONE, filed with the demand.
and additional amendments:
NONE

5. (Some) amendments are considered to go beyond the disclosure as filed:
NONE

What is Claimed Is:

1. A digital broadcasting system for transmitting a broadcast signal, said broadcast signal being transmitted from an earth station, comprising:

a satellite for receiving said broadcast signal from said earth station and for transmitting a satellite signal comprising said broadcast signal on a first carrier frequency; and

a terrestrial repeater for receiving said satellite signal and for generating and transmitting a terrestrial signal from said satellite signal comprising said broadcast signal on a second carrier frequency that is different from said first carrier frequency, said terrestrial signal being modulated by said terrestrial repeater in accordance with a multipath-tolerant modulation technique.

2. A system as claimed in claim 1, wherein said terrestrial repeater is operable to modulate said terrestrial signal using at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptively equalized time division multiplexing, multicarrier modulation, and code division multiplexing.

3. A system as claimed in claim 1, wherein said satellite signal is modulated in accordance with at least one of time division multiplexing and code division multiplexing.

4. A system as claimed in claim 1, wherein said terrestrial repeater is operable to modulate said terrestrial signal using multicarrier modulation.

5. A system as claimed in claim 4, wherein said terrestrial repeater is operable to receive said satellite signal and to demodulate said satellite signal into a baseband signal prior to modulating said baseband signal using multicarrier modulation.

6. A system as claimed in claim 1, wherein said satellite signal is assigned a first code division multiple access channel code and said terrestrial signal is assigned a second code division multiple access channel code.

7. A system as claimed in claim 1, further comprising a second satellite, said second satellite being operable to receive said broadcast signal from said earth station and to

transmit a second satellite signal comprising said broadcast signal on said first carrier frequency and delayed by a predetermined period of time with respect to the transmission of the first satellite signal.

8. A terrestrial repeater for retransmitting satellite signals to radio receivers, comprising:

a terrestrial receiver for receiving said satellite signals; and

a terrestrial waveform modulator for generating terrestrial signals from said satellite signals, said terrestrial signals being modulated by said terrestrial waveform modulator in accordance with multicarrier modulation;

wherein said satellite signals are transmitted from a satellite using a first carrier frequency, and said terrestrial waveform modulator is operable to transmit said terrestrial signals to said radio receivers using a second carrier frequency that is different from said first carrier frequency.

9. A terrestrial repeater as claimed in claim 8, wherein said terrestrial waveform modulator comprises:

a time division demultiplexer for demultiplexing said satellite signals from a serial time division multiplexed bit stream into a plurality of parallel bit streams; and

an inverse fast Fourier transform device for generating a digital analog signal comprising a plurality of discrete Fourier transform coefficients.

10. A method for converting a time division multiplexed bit stream into a plurality of multicarrier modulated signals at a terrestrial repeater, comprising the steps of:

receiving said time division multiplexed bit stream from a satellite;

dividing said time division multiplexed bit stream into a plurality of parallel bit paths;

representing each of a predetermined number of bits in each of said plurality of bit paths as a symbol comprising an imaginary component and a real component;

providing said symbols to parallel inputs of an inverse Fourier transform converter as complex number frequency coefficient inputs to generate outputs which comprise modulated, narrow-band, orthogonal carriers; and

transmitting said modulated, narrow-band, orthogonal carriers from said terrestrial repeater.

11. A method as claimed in claim 10, further comprising the step of generating a guard interval for said carriers.

12. A method as claimed in claim 11, wherein said generating step comprises the steps of:

allocating a fraction of the symbol period corresponding to the duration of each of said symbols to guard time; and

reducing the duration of each of said symbols.

13. A method as claimed in claim 12, wherein said reducing step comprises the steps of:

storing said outputs of said inverse Fourier transform converter in a memory device every said symbol period; and

reading from said memory device after each said fraction of said symbol period has elapsed.

14. A method as claimed in claim 11, wherein said generating step further comprises the step of filling said guard interval with a subset of said outputs of said inverse Fourier transform.

15. A method as claimed in claim 10, further comprising the step of inserting a synchronization symbol every predetermined number of said symbol periods to synchronize a sampling window corresponding to said fraction of said symbol period with respect to said carriers every said symbol period at a receiver for said plurality of multicarrier modulated signals.

16. A method as claimed in claim 10, further comprising the step of puncturing said time division multiplexed bit stream to reduce the total bandwidth associated with said carriers.

17. A method as claimed in claim 16, wherein said puncturing step comprises the step of selectively eliminating bits from said time division multiplexed bit stream prior to providing said symbols to said parallel inputs of said inverse Fourier transform converter.

18. A digital broadcasting system for transmitting a broadcast signal, said broadcast signal being transmitted from an earth station, comprising:

a first satellite configured to receive said broadcast signal from said earth station and to transmit a time division multiplexed satellite signal comprising said broadcast signal;

a terrestrial repeater configured to receive said satellite signal and to generate and transmit a terrestrial signal from said satellite signal comprising said broadcast signal, said terrestrial signal being modulated by said terrestrial repeater in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing, and multicarrier modulation.

19. A digital broadcasting system as claimed in claim 18, wherein said satellite signal is transmitted using a first carrier frequency, and said terrestrial signal is transmitted using a second carrier frequency that is different from said first carrier frequency.

20. A digital broadcasting system as claimed in claim 18, further comprising at least one radio receiver configured to receive said satellite signal and said terrestrial signal, said radio receiver comprising a diversity combiner for generating an output signal from at least one of said satellite signal and said terrestrial signal.

21. A digital broadcasting system as claimed in claim 18, further comprising a second satellite configured to receive said broadcast signal from said earth station and to transmit a second time division multiplexed satellite signal comprising said broadcast signal, said second satellite signal being delayed with respect to said first satellite signal by a selected time delay.

22. A digital broadcasting system as claimed in claim 21, further comprising at least one radio receiver configured to receive said first satellite signal, said second satellite signal and said terrestrial signal, to delay at least one of said first satellite signal and said terrestrial signal in accordance with said selected time delay, and to generate an output signal from at least one of first satellite signal, said second satellite signal and said terrestrial signal.

23. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner and a switched combiner, said radio receiver using said diversity combiner to perform maximum likelihood decision combining of said first satellite

signal and said second satellite signal and said switched combiner to select between the output of said diversity combiner and said terrestrial signal depending on which of said output of said diversity combiner and said terrestrial signal has the least number of bit errors.

24. A digital broadcasting system as claimed in claim 22, wherein said radio receiver comprises a diversity combiner to perform maximum likelihood decision combining of said first satellite signal, said second satellite signals and said terrestrial signal.

25. A receiver for receiving a broadcast signal in a combined satellite and terrestrial digital broadcasting system, comprising:

a first receiver arm for receiving a first satellite signal transmitted from a first satellite on a first carrier frequency, said first satellite signal comprising said broadcast signal and being modulated in accordance with at least one of time division multiplexing and code division multiplexing, said first receiver arm comprising a demodulator for recovering said broadcast signal;

a second receiver arm for receiving a terrestrial signal transmitted from a terrestrial station on a second carrier frequency, said terrestrial signal comprising said broadcast signal and being modulated in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing, and multicarrier modulation, said second receiver arm comprising a demodulator for recovering said broadcast signal; and

a combiner for generating an output signal from at least one of said third satellite signal and said terrestrial signal.

26. A receiver as claimed in claim 25, further comprising:

a third receiver arm for receiving a second satellite signal from a second satellite that is delayed with respect to said first satellite signal in accordance with a selected time delay, said second satellite signal comprising said broadcast signal and being modulated in accordance with the corresponding at least one of time division multiplexing and code division multiplexing employed by said first satellite signal, said third receiver arm comprising a demodulator for recovering said broadcast signal; and

a delay device for delaying said first satellite signal in accordance with said selected time delay, said combiner being operable to generate an output signal from at least one of said first satellite signal, said second satellite signal and said terrestrial signal.

27. A method for transmitting a broadcast signal to a radio receiver, comprising the steps of:

modulating said broadcast signal for transmission to said radio receiver as a first signal in accordance with at least one of time division multiplexing and code division multiplexing;

transmitting said first signal to said radio receiver from a first satellite on a first carrier frequency;

modulating said broadcast signal at a terrestrial station for transmission to said radio receiver as a second signal in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing, and multicarrier modulation; and

transmitting said second signal to said radio receiver from said terrestrial station on a second carrier frequency that is different from said first carrier frequency.

28. A method as claimed in claim 27, wherein the step of modulating said broadcast signal as said second signal comprises the steps of:

receiving said first signal at said terrestrial station; and

performing baseband processing of said first signal prior to modulating in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing, and multicarrier modulation.

29. A method as claimed in claim 28, further comprising the step of receiving said first signal and said second signal at said radio receiver.

30. A method as claimed in claim 29, further comprising the step of demodulating each of said received first signal and said received second signal to remove said respective modulations and to recover a first recovered broadcast signal and a second recovered broadcast signal, respectively.

31. A method as claimed in claim 30, further comprising the step of generating an output broadcast signal from said first recovered broadcast signal and said second recovered broadcast signal.

32. A method as claimed in claim 31, wherein said generating step comprises the step of performing maximum likelihood combining of said first recovered broadcast signal and said second recovered broadcast signal.

33. A method as claimed in claim 27, further comprising the steps of:

modulating a broadcast signal for transmission to said radio receiver as a third signal in accordance with at least one of time division multiplexing and code division multiplexing;

transmitting said third signal to said radio receiver from a second satellite, said transmission being delayed with respect to the transmission of said first signal by a predetermined period of time.

34. A method as claimed in claim 33, further comprising the steps of:

receiving said first signal, said second signal and said third signal at said radio receiver;

demodulating each of said first signal, said second signal and said third signal to remove said respective modulations and to recover a first recovered broadcast signal, a second recovered broadcast signal and a third recovered broadcast signal, respectively; and

generating an output broadcast signal from at least one of said first recovered broadcast signal, said second recovered broadcast signal and said third recovered broadcast signal.

35. An indoor reinforcement system for receiving satellite signals transmitted by a digital broadcasting system using a radio receiver located indoors, comprising:

a line of sight antenna for receiving line of sight satellite signals;

a radio frequency front-end unit connected to said line of sight antenna for passing frequency spectrum comprising said satellite signals with low noise;

an indoor amplifier;

a cable for connecting said radio frequency front-end unit to said indoor amplifier; and

an indoor re-radiating antenna connected to said indoor amplifier, said indoor re-radiating antenna having a power level selected to be sufficiently high to achieve satisfactory indoor reception of said satellite signals at radio receivers at indoor locations where line of sight reception of said satellite signals is not possible and sufficiently low to prevent interference by said satellite signals transmitted between said indoor re-radiating antenna and said line of sight antenna.

36. An indoor reinforcement system as claimed in claim 35, wherein said satellite signals are characterized by a selected symbol period, and the duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is maintained to be less than a selected amount of said symbol duration by limiting the length of said cable.

37. An indoor reinforcement system as claimed in claim 36, wherein said duration of the transmission of said satellite signals between said line of sight antenna and said indoor re-radiating antenna is no more than between 20 percent and 25 percent of said selected symbol period.

38. A reinforcement system for receiving satellite signals transmitted by a digital broadcasting system using a radio receiver located outdoors, wherein said satellite signals are characterized by a selected period, said reinforcement system comprising at least two terrestrial repeaters, said terrestrial repeaters being characterized by a height h and being spaced apart by a distance d, the slant distance $(d^2 + h^2)^{1/2}$ from one of said terrestrial repeaters to said radio receiver being selected to limit a delay in reception of said satellite signals at said radio receiver from one of said terrestrial repeaters to between 20 percent and 25 percent of said symbol period.

39. A digital broadcasting system for transmitting a broadcast signal to a radio receiver, said broadcast signal being transmitted by an earth station, comprising:

a satellite configured to receive said broadcast signal from said earth station and to transmit a satellite signal comprising said broadcast signal to said radio receiver on a first carrier frequency; and

at least one terrestrial repeater configured to receive said satellite signal and to generate and transmit a terrestrial signal from said satellite signal comprising said broadcast signal to said radio receiver on a second carrier frequency that is different from said first carrier frequency, wherein said satellite signal and said terrestrial signal are each modulated using a multipath-tolerant modulation technique.

40. A system as claimed in claim 39, wherein said satellite signal is modulated in accordance with code division multiplexing.

41. A system as claimed in claim 39, wherein said terrestrial signal is modulated in accordance with at least one of adaptive equalized time division multiplexing, coherent frequency hopping adaptive equalized time division multiplexing, code division multiplexing, and multicarrier modulation.